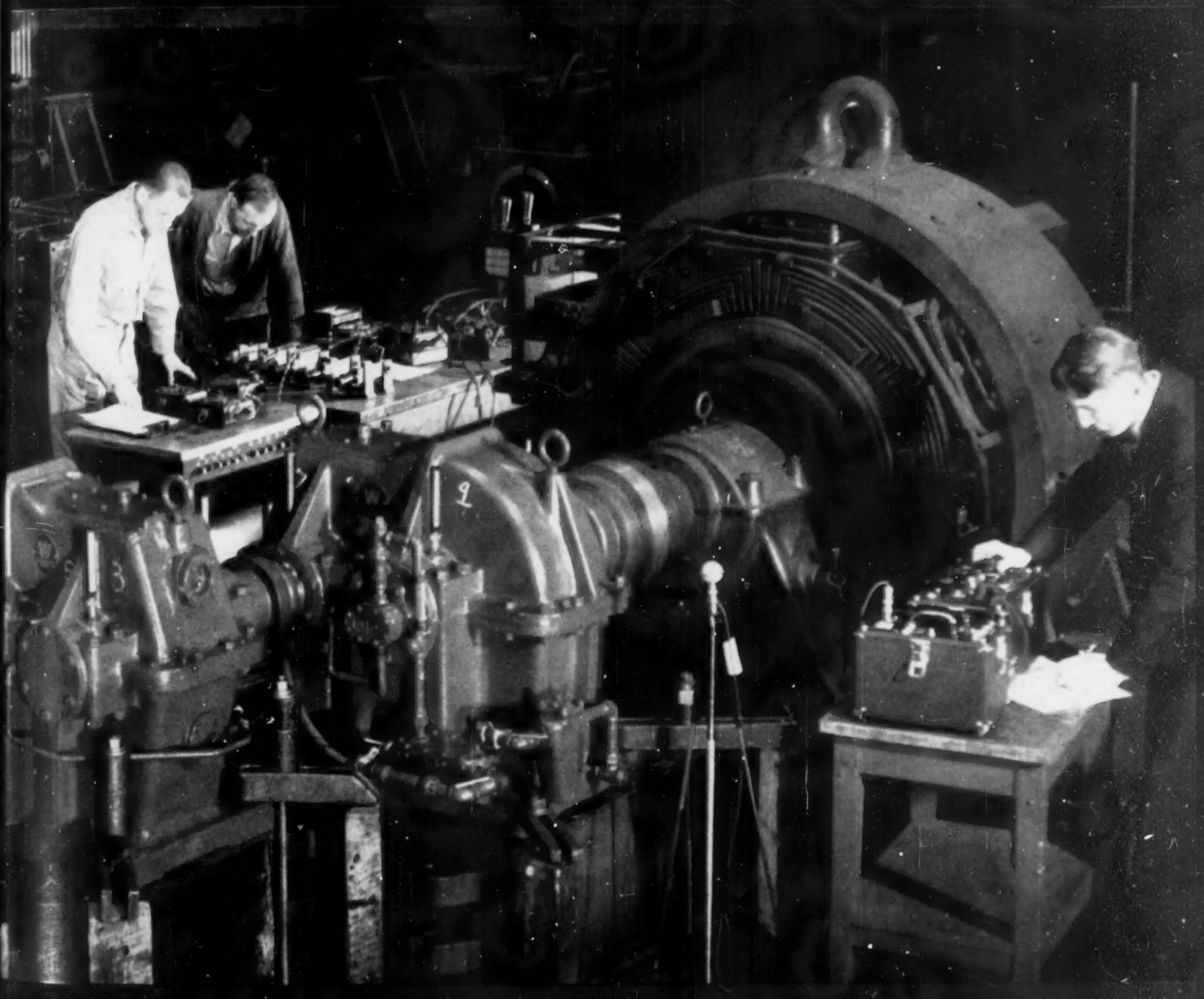
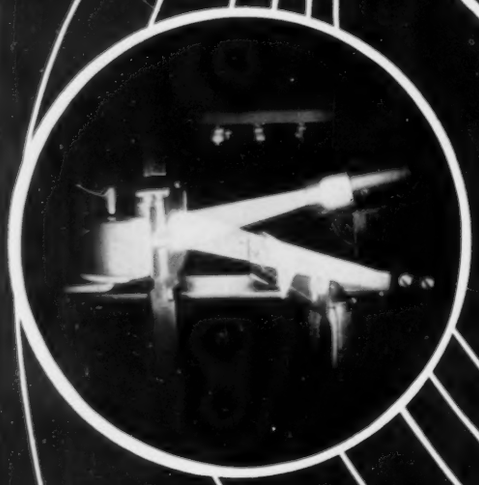
Instruments

THE MAGAZINE OF Measurement and Control

Vol. XIII
AUG. 1940
No. 8



TAG



3 TO 6 FURNACES CONTROLLED BY ONE CELECTRAY

with photoelectric detection employing - -

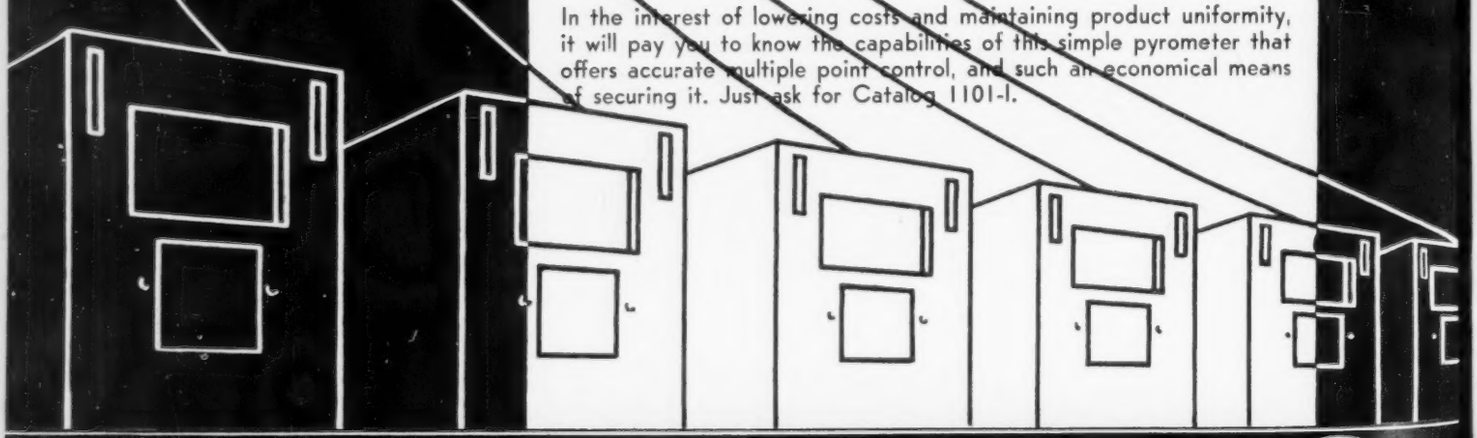
A PHOTOELECTRIC TUBE
A MIRROR GALVANOMETER
A BEAM OF LIGHT

Now it is possible to control 3 to 6 furnaces, or a 3- to 6-zone furnace, with a single, comparatively inexpensive instrument . . . Only TAG has provided this needed, economical means of multiple point control with a new development — CELECTRAY Multiple Point Indicating Controller.

The closeness of control expected of some single point instruments is frequently surpassed by this New CELECTRAY, due to its extraordinary high sensitivity and quick action.

There are many other notable CELECTRAY Features, including independent control point setting and terminals for connecting to motor operated valves or magnetic contactors without using intermediate external relays.

In the interest of lowering costs and maintaining product uniformity, it will pay you to know the capabilities of this simple pyrometer that offers accurate multiple point control, and such an economical means of securing it. Just ask for Catalog 1101-I.



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Park & Nostrand Ave's., Brooklyn, N. Y.

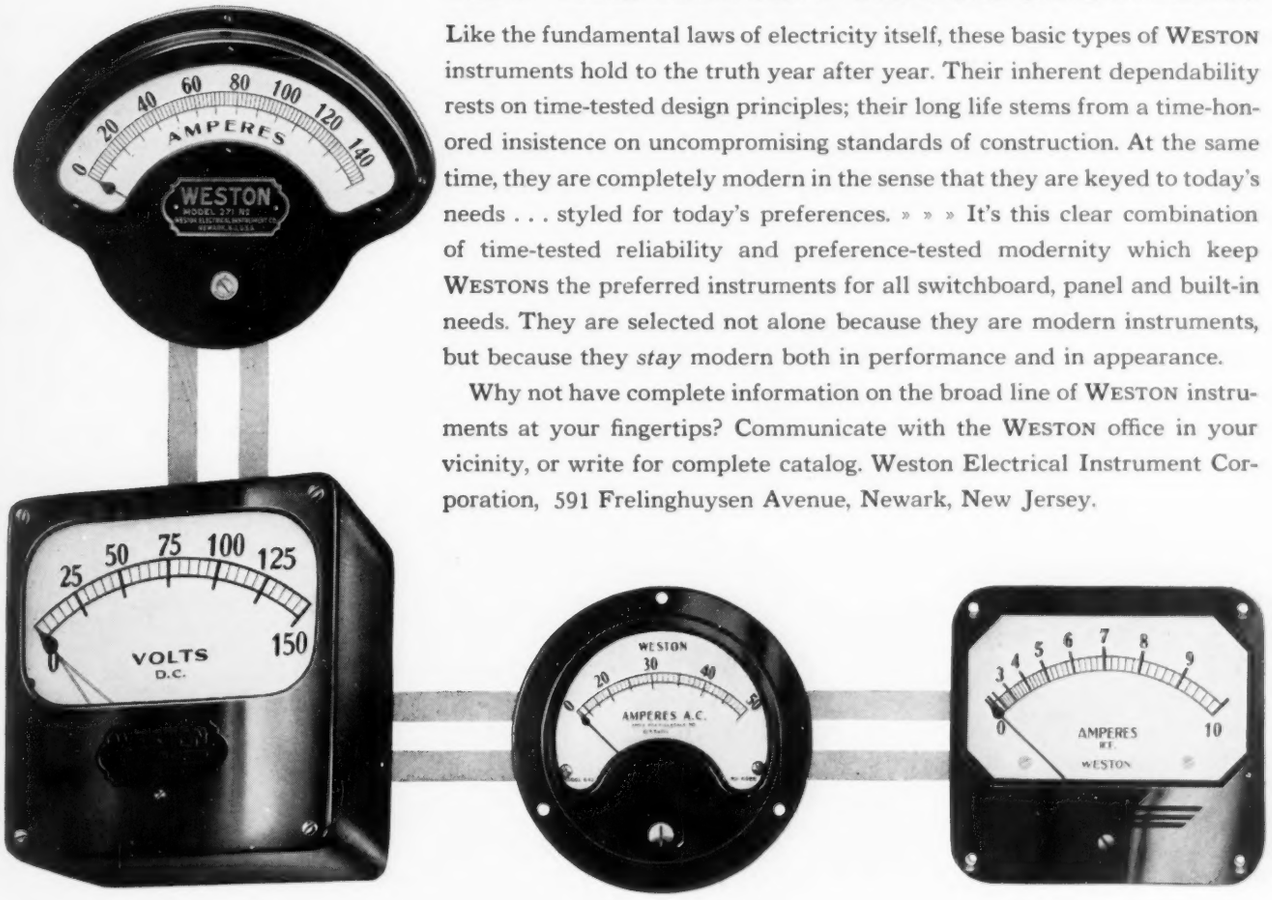
TAG LIABUE BROOKLYN N.Y. U.S.A.

Time Tested FUNDAMENTALS

$I=\frac{E}{Z}$ $R=\frac{P}{I^2}$ $C=\frac{Q}{E}$ $P=EI$ $f=\frac{1}{T}$

$W=PT$ $f=\frac{1}{T}$ $I=\frac{E}{Z}$ $R=\frac{P}{I^2}$ $P=EI$

for Electrical Measurement



Like the fundamental laws of electricity itself, these basic types of WESTON instruments hold to the truth year after year. Their inherent dependability rests on time-tested design principles; their long life stems from a time-honored insistence on uncompromising standards of construction. At the same time, they are completely modern in the sense that they are keyed to today's needs . . . styled for today's preferences. » » » It's this clear combination of time-tested reliability and preference-tested modernity which keep WESTONS the preferred instruments for all switchboard, panel and built-in needs. They are selected not alone because they are modern instruments, but because they *stay* modern both in performance and in appearance.

Why not have complete information on the broad line of WESTON instruments at your fingertips? Communicate with the WESTON office in your vicinity, or write for complete catalog. Weston Electrical Instrument Corporation, 591 Frelinghuysen Avenue, Newark, New Jersey.

Laboratory Standards . . . Precision DC and AC Portables . . . Instrument Transformers . . . Sensitive Relays . . . DC, AC, and Thermo Switchboard and Panel Instruments.

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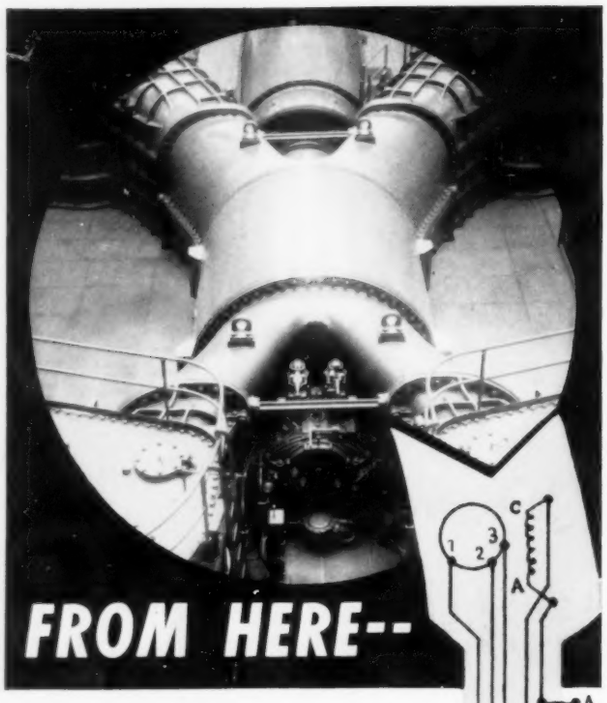
Specialized Test Equipment . . . Light Measurement and Control Devices . . . Exposure Meters . . . Aircraft Instruments . . . Electric Tachometers . . . Dial Thermometers.

FOR OVER 52 YEARS LEADERS IN ELECTRICAL MEASURING INSTRUMENTS



VIA

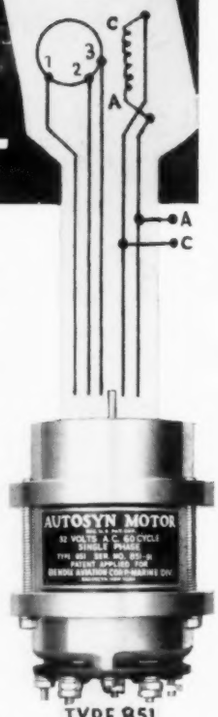
BENDIX-CORY

AUTOSYN

SELF-SYNCHRONIZING

SIGNALING UNITS

THE circuit diagram in the arrow shows how simply a pair of Bendix-Cory Autosyns transmit instrument readings to remote points. Pressure, station load, r.p.m., position, rate-of-flow, count, dimension, liquid level —almost any measure—may thus be read at a distance in one or several places. Several sizes and types. Type 851 (shown) produces 2.5 inch-ounces of torque at 90° angular displacement —safe continuous operating torque 1.1 inch-ounces. Weight 15.3 ozs. Dimensions $2\frac{3}{8}$" x $3\frac{15}{32}$". Other Autosyns operate within an accuracy range of 1° + or − (½° + or − on special order).



One Autosyn Transmitter can actuate several variously located receivers for remote instrument readings.

BENDIX AVIATION CORPORATION
MARINE DIVISION
754 Lexington Ave. Brooklyn, New York

Instruments

THE MAGAZINE OF MEASUREMENT and CONTROL

Vol. XIII AUGUST 1940 No. 8

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M. F. BEHAR, Editor

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Instruments
THE MAGAZINE OF Measurement and Control
M. F. BEHAR, Editor

"Elective Courses"

GOOD technical or industrial magazines—and there are many of them—provide one of the most effective agencies for the education of industrial technicians, research men and production executives. Schools publish annual catalogs describing the purposes as well as the contents of their courses; magazines should likewise frequently lift the veil.

Every honest-to-goodness magazine—unendowed, unsubsidized and therefore depending wholly for its existence upon excellence of service to its subscribers—must obtain exact knowledge as to how best to render this service.

More than once you have been asked, on this page, to express preference for the types of articles which *Instruments* should publish in order to be of the greatest possible service to you the instrument users of America.

In addition to these frequent public notices, of course, we have made it a practice (and will continue to make it a practice) to put this same question to readers whom we meet—those whom we happen to meet at technical meetings and those whom we travel to meet. We ask the advice, also, of many readers with whom we correspond. Occasionally, the Circulation Department has even sent out questionnaires to representative lists of subscribers. We always have tried to keep an open mind, but even if we had preconceived notions the overwhelming evidence would force recognition of certain outstanding facts:

The regular feature unanimously elected first choice is "The Month's New Instruments." (It is for its news value, rather than for its educational value, that it rates first, but readers know how much it differs from the usual "free publicity" new-product columns.)

The only type of article desired by all readers without exception is what might be called the "practical educational" type. A few readers prefer brief stories of means and results; a few prefer expositions of underlying theories; but all agree on wanting a combination of "what-is-it" and "how-it-works," dealing with a broad class of measuring instruments, or testers, or controllers.

As to what constitutes a practical article, opinions differ widely. Some articles warmly praised as practical were actually so devoid of application data that we had considered them to be "theoretical." There emerges the conclusion which we reported on this page some years ago: what readers want *and need* is not so much one kind of dish as a *balanced diet:* long, thorough texts, printed in handy instalments; brief accounts of how actual problems were solved; now and then, an authoritative exposition of underlying theory, necessarily couched in the exact language of mathematics. And even a dash of seasoning!

The letters which make the deepest impression upon the publisher and the editor are the unsolicited letters coming from "unknown friends"—readers not personally known to anyone in this office, who are enthusiastic for the advancement of Instrumentation and who have grown fond of *Instruments* over a number of years. With remarkable unanimity these faithful readers recommend that we reprint the serials on the measurement and control of temperature, humidity, pressure, etc., which ran in 1930-'33.

The first few letters of this kind, we confess, received less consideration than they deserved, because it was possible that the writers were merely paying compliments (the author of these old serials is now editor of *Instruments*).

But false modesty had to be shed when it became obvious that the most urgent of these requests came from old subscribers who head instrument department in modern plants and who are in large measure responsible for the education of their men. Specifically, recent requests for reprinting the serial on temperature measurement and control are particularly urgent. This serial came out in 1932 in book form; this book has been out of print since 1935; and some instrument department heads are almost frantic in their pleas that this text be made available for their men's instruction.

It is most unusual for a magazine to reprint articles which it had published before, but it is inexcusable for a magazine to fail to meet the needs of its readers. The Instruments Publishing Company has directed us, therefore, to publish a serial on Industrial Temperature Measurement and Control, beginning in the September issue. This will not be a word-for-word reprint of the book bearing the same name (which book has of course been in process of revision since 1933). The new text will be shorter. It will be more up-to-date. It will—as far as is humanly possible—meet the practical needs of practical men who use industrial instruments in all industries.

As an extra service to readers, this text is scheduled to be published in only four instalments: industrial thermometry in September, industrial pyrometry in October, temperature control principles in November and temperature control devices in December.

Returning to the analogies between engineering schools and technical magazines: The most useful agencies (institutional or editorial) are those which strive to *anticipate* needs. For example, "everybody knows" *today* that America's gravest needs are related to defense, but only a handful foresaw this need during the five or six years before that fateful First of September 1939. So few were the civilian technical schools blessed with wise foresight that the inauguration of the Ordnance Department's Gage Laboratory at N.Y.U. in 1937 was a big event. So few were the civilian technical magazines printing national defense editorials that five years ago the Commandant of the Army Industrial College, at a dinner in Washington, read aloud our April 1935 editorial and referred to "the only" editor of a non-military journal who dared to sound warnings when to do so was unpopular.

To be sure—as an engineering professor has just told us—schools find it more expensive to anticipate than do magazines. If a university had built an aerodynamics laboratory in 1900, students—even math sharks—would have shunned the course and the deserted building would have evoked jeers. Whereas if a magazine gives a little space to "anticipatory" subjects and most space to "popular" subjects, hardly anybody knows the difference. Yes, that's one way of putting it, but the fact remains that in order to be able to anticipate needs, one must be able to distinguish between needs and wants, and one must have the guts to supply needs. History (Roman and modern) teaches that handing out "bread and circuses" results in flashy success followed by decay and ruin. Popular colleges with huge enrollments do not really serve their myriads of students and they contribute little to the nation, whereas the serious schools which look to the future of their students do an honest job of anticipation. Mass-circulation periodicals which simply follow the crowd do not really serve the crowd but betray the crowd and harm the nation, whereas magazines which constantly ascertain and analyze needs . . . (finish it yourself!)

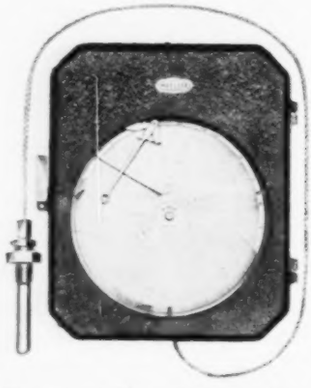
MOELLER
PRECISION GRADE INSTRUMENTS

☆

Moeller mercury thermometers are made with the Moeller Glass Red Reading Column making them easy to read under varying light conditions, at a considerable distance and over a wide range.

☆

Moeller dial thermometers are made in various scale ranges up to 1000°F. or equivalent. Metal and Phenolite cases.



Moeller recording thermometers are likewise furnished in various ranges up to 1000°F. or equivalent. Round and square cases as preferred.

Also HYGROMETERS
RECORDING PSYCHROMETERS
BAROMETERS HYDROMETERS
MARINE INSTRUMENTS, ETC.

Write for catalog.

MOELLER INSTRUMENT COMPANY
132nd STREET and 89th AVENUE
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Sales Representatives in Principal Cities

THE MONTH'S NEW INSTRUMENTS

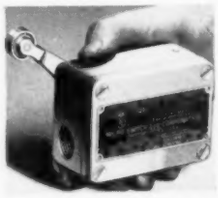
In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions. When writing to manufacturers directly, please mention this department as your source of information. Or write to Information Section, Instruments Publishing Company.

Industrial Humiditstat, Insertion Form

New insertion form humidity controller is designed to be suitable for use where dust, dirt and other adverse service conditions would prevent satisfactory operation of other types. Humidity-responsive and actuating element is maker's specialty, a Friez multiple human hair element. Another feature is a switch mechanism fully enclosed in a molded plastic case. Control of both humidifying and dehumidifying is provided over a range of 10% to 100% relative humidity, with a sensitivity of ±1%. Known as the "Type H/61," this new instrument is suitable for use in bakers' proof-boxes, incubators, low-temperature ovens, test cabinets and similar applications.—*Julien P. Friez & Sons, Div. of Bendix Aviation Corp., Baltimore St. & Central Ave., Baltimore, Md.*

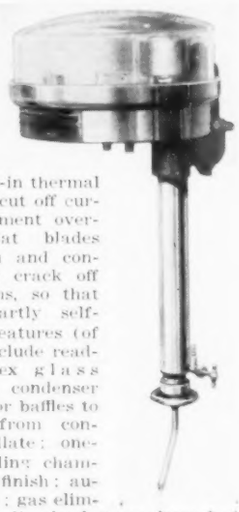
Explosion-proof Housed "Micro Switch"

New explosion-proof housing, 3⅝" × 2½" × 2", is designed to make use of "Micro Switch" as switching element. "Explosion Proof Micro Switch" is Underwriters' Laboratories listed for hazardous locations, Class I, Groups C and D, and Class II, Group G. These listings are for atmospheres containing vapors of ethyl ether, gasoline, alcohol, acetone, lacquer solvents, etc., and for grain dusts. Types of actuation now available are roller arm with axis of roller either parallel to or at right angle to arm; and a bullet-nose push rod type. All types are said to have precision characteristics with a maximum movement differential of 0.001". Where a foot or lug type of mounting is desirable, a universal mounting strap is available. Removable cover plate provides access to terminals, which accept No. 14 solid wire. Switching unit enclosed within cast iron housing is standard "Micro Switch" with a separate Underwriters' listing of 1200 watts up to 600 volts a.c. Switch may be easily removed for inspection or change. Within listed rating a life of over a million operations may be expected. S-p.d-t. contact arrangements now available.—*Micro Switch Corp., Freeport, Ill.*



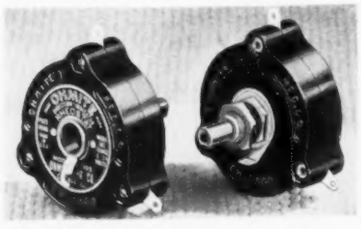
Laboratory Water Stills

Six new electrically-heated laboratory water stills are announced. Three capacities: ½, 1 and 1½ g.p.h.; each size available in two types, one with standard immersion heaters and the other with heavy-duty heating elements. The latter, for use in hard water districts where scale tends to build up rapidly, have a built-in thermal safety switch to cut off current in case element overheats, have flat blades whose expansion and contraction tend to crack off scale as it forms, so that unit is also partly self-cleaning. Other features (of all new stills) include readily-removed Pyrex glass covers; solid tin condenser tubes; triple vapor baffles to prevent spray from contaminating distillate; one-piece copper boiling chambers; chromium finish; automatic operation; gas eliminator to remove dissolved gases from feed water; and a deconcentrator which, it is said, automatically removes impurities that cause foam and scale. Maker states that all stills in this new line will produce distilled water equal of that usually produced only by double or triple distilling; also that, because of counter-flow principle of operation, cost of distillate is about 4 cents per gallon, depending on the cost of electric current.—*F. J. Stokes Machine Co., 3826 Tabor Road, Philadelphia, Pa.*



Direction-indicator Rheostat

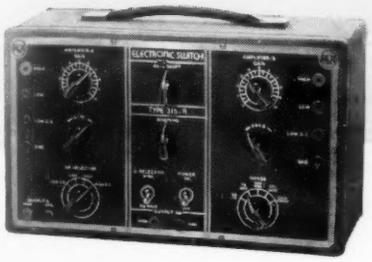
New "Model DR-125" Direction Indicator Rheostat is connected to the moving part of rotary-beam antennas, direction-finding loop antennas, wind-vanes, etc., in order to send an indication of the position to a remote point. Aircraft uses are obvious. Industrial uses include use at an operator's desk to show position of valves, water gates, dampers, etc. Rheostat has a 360° continuous winding, is designed for use on d.c. up to 24 volts. It consists of a glazed ceramic housing 1⅞" diam. and 13/16" deep behind panel. Mounted by a ⅜"-32 bushing and nut on any panel up to ¼" maximum. Equipped with non-turn washer. Shaft ¼". —*Ohmite Manufacturing Co., 4835 Flournoy St., Chicago, Ill.*



For Simultaneous Oscillographic Comparison of

TWO FUNCTIONS

...NEW RCA Model 315-A ELECTRONIC SWITCH



OSCILLOGRAPHIC traces of two separate functions can be viewed *simultaneously* on any oscillograph, for waveform and phase comparisons, with this new RCA Model 315-A Electronic Switch. Two separate amplifier channels are automatically "keyed" by a variable-frequency square-wave generator to yield a portion of one signal alternating rapidly with a portion of the other signal. On the screen, both functions appear visually continuous. Switching-frequency is variable from 20 to 15,000 cycles; square-wave generator from 10 to 7,500 cycles.

Such applications as Power Factor relations under varying loads may be visually shown simply by connecting the voltage-applied to one amplifier input, and the current-flow to the other amplifier, giving simultaneous *I* and *E* curves with the angle of lag clearly indicated for each condition * * * Electronic amplifiers may be checked directly for phase and wave-form distortion by connecting the input signal to one amplifier channel on the 315-A and the output signal to the other amplifier channel. Smooth-working controls on the panel of the 315-A permit varying the amplitude and position of these traces until respective peak-levels coincide. Write for complete data and literature.

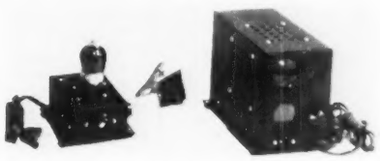
Over 380 million RCA Radio Tubes have been bought by radio users

RCA *Measuring Equipment*

RCA Mfg. Co., Inc. • Camden, N. J., U. S. A.
A Service of the Radio Corporation of America

Photoelectric Devices

A new complete line of photoelectric units and "Eby-alarms" is announced, said to embody circuits and engineering features for advanced in detail and design. All com-



ponent parts are said to have wide safety factors insuring continuous operation. New line comprises eight numbers from a "Beginner's Unit" to a burglar alarm with intermediate units, self-contained or independent light sources, for office, industrial, and commercial applications. Illustration shows the "Beginner's" and "Heavy Duty" units. All operate on 110 to 120 volts a.c., 50 to 60 cycles. D.c. models will be available shortly. —*Hugh H. Eby, Inc., 4700 Stenton Ave., Philadelphia, Pa.*

Signal Generator

New "Model 1632" signal generator is claimed to have "accuracy and stability beyond anything heretofore demanded in the test field." It provides continuous coverage

of frequencies from 100 kc. to 120 mc. on 10 bands. Metered output to multiplier and attenuator. Heterodyne detector permits checking oscillator, or beating with another oscillator, without a receiver. Output available at end of coaxial cable minimizes losses and disturbance to circuit under test. Provision for external modulation at audio or radio frequencies. Voltage regulator tube regulates voltage for the oscillator and improves stability. Permeability adjustment and tubular air-trimmer capacitors are used throughout. — *The Triplett Electrical Instrument Co., Bluffton, Ohio.*

Multi-purpose Industrial and Military Watch

New "Clebar Multichron" is said to be particularly adapted for industrial research work as well as military and sporting uses. In addition to wrist-watch and 1/5 sec. stop-

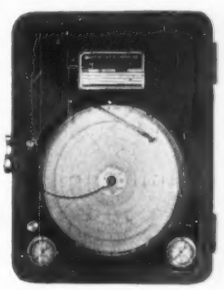
watch functions it has a telemeter scale based on normal velocity of sound in air; and the three innost circles permit obtaining miles-per-hour readings. Upper single hand registers revolutions of sweep-second hand up to 30-minutes.—*Clebar Watch Co., 551 Fifth Ave., New York City.*

BAILEY METER CONTROL SYSTEM

The Mark of
Effective Control

Process Control for sensitive, stable automatic control of temperature, pressure, liquid level, flow and other factors as applied to industrial processes. Responds to changes quickly, without overtravel or hunting. Ask for Bulletin No. 101.

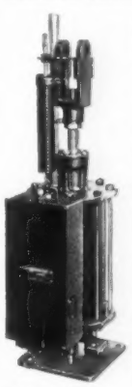
Combustion Control that is simple but *complete* for providing economical operation of boilers of 200 h. p. and larger. Details in Bulletin No. 102.



Recorder-Controller

Boiler Meters for recording combustion conditions and guiding boiler operators. Described in Bulletin No. 44.

Multi-Pointer Gages for indicating factors such as draft, pressure, temperature and speed. These Gages are available with any number of pointers and any scale combination; in either the oil sealed bell or diaphragm construction.



Control Drive

Flow Meters for indicating, recording and integrating the flow of steam, water, sewage, air, gas and other fluids. Bulletins No. 39 and 300.

Recorders for pressure, temperature, drafts, liquid level and other factors.

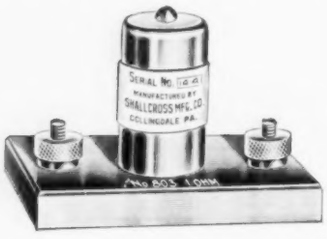
G-3

BAILEY METER COMPANY

1041 Ivanhoe Rd., Cleveland, Ohio

Standard Resistors

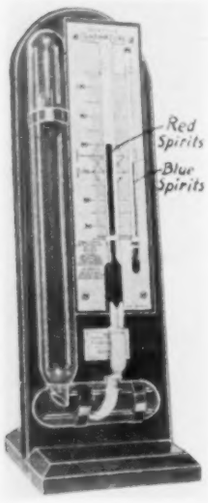
In addition to maker's custom-built resistance standards, there is announced a line of "Secondary Standard Resistors" comprising nine models, from 1 ohm to 10



megohms, accuracy 0.1%, maximum load 1 watt. Illustration shows 1-ohm "No. 803P." Windings are bifilar for values up to 1000 ohms; balanced rev. pie to 1 megohm and nickel-chrome for the 10-megohm "No. 810." Each unit is mounted on a substantial base, fitted with a dust cover. New units are said to fill the need for high-quality standards of moderate accuracy at a moderate price.—*Shallcross Mfg. Co., 10 Jackson Ave., Collingdale, Pa.*

Air Condition Indicator

New "Bailey-Parsons Therhumiter" belongs to the class of air-condition indicating instruments which react to a combination of effects of temperature, humidity and circulation, rather than to only one of these three factors. It comprises two thermometers and a specially-devised scale; Larger unit is a red-spirit effective temperature thermometer (with two communicating bulbs, one dry and one wet); smaller unit is a blue-spirit air-temperature thermometer; scale is so designed that foremen, superintendents, teachers and others responsible for work-room or classroom conditions can determine at a glance whether to adjust temperature, or ventilation, or both, in order to provide desired effective temperature when humidity cannot be adjusted; or what to do when all three factors can be adjusted. It is said that "Therhumiter" is only instrument permitting instant decision by operating engineers as to necessary adjustments of all controls of complete air-conditioning equipment without consulting charts. New device is 9" long, is available in desk type (illustrated) and wall type. A carrying case is also available.—*Weksler Thermometer Co., 535 Pearl St., New York City.*



Snap-action Switch

New "S611 Con-Tac-Tor" snap-acting, non-magnetic switch is said to have a unique combination of characteristics, among which are small size (2" × 1" × ¾"), entirely enclosed in a black Bakelite case, high electrical rating (1 h.p. 110v. a.c., 1½ h.p. 220v. a.c.), universal mounting (may be installed in any position), vibration-proof, low operating effort (4.3 ounces), and speedy operation. Factory tests showed a half million operations with no perceptible change in efficiency. S-p.d-t. switch with three built-in terminals is designed to "break" one set of contacts and then "make" the other set of contacts when actuated. There is said to be no overlapping

of "break" and "make." Following hook-ups are possible: (1) to "make" and "break" a two-wire circuit. (2) to "break" one circuit and "make" another circuit when two circuits with a common wire are used. In either hook-up direct or reverse action may be obtained by reversing the two outside terminals. Types available include: "push-in" self restoring actuator "pull-out" self restoring actuator; "push-in," "pull-out" non-self restoring actuator. — *Minneapolis-Honeywell Regulator Co., 2950 Fourth Ave., South, Minneapolis, Minn.*

Thermometers
Hygrometers
Psychrometers
Hydrometers

Several hundred types and varieties of instruments are described in new Catalog 110, but since ALL of them are produced in our own factory under our own experts' supervision, the best materials and high-grade workmanship characterize EACH of them.

Our customers find special satisfaction in the choice of FOUR different styles of thermometer glass: 1. White enamel back; 2. yellow enamel back; 3. Hespe; 4. red-reading mercury.

TWO WIDELY USEFUL NUMBERS

(Left) No. 169. For pressure-cooking processes, with two scales: 170-270°F. and 0-30 lbs. pressure. 9" scale length. (Right) No. 326. Max. & min. registering thermometer in 12" shelter type copper case. Approx. range minus 40 to 120°F.

Weksler Thermometer Corporation
535 PEARL STREET NEW YORK, N. Y.

TUBE PHOTOMETER
with ELECTRONIC AMPLIFICATION
for
Measuring Low Light on Small Areas

- Suitable for Spectrophotometry, for measuring Tyndall light, fluorescence and weak U.V. radiation, for densitometry and light measurements on focusing screens of micro-cameras.
- Self-contained, portable, operated from power line, fully balanced for line voltage variations, direct reading.
- High-gain DC-amplifier also applicable to tube voltmeters, pH meters, insulation meters, ionization current indicators.

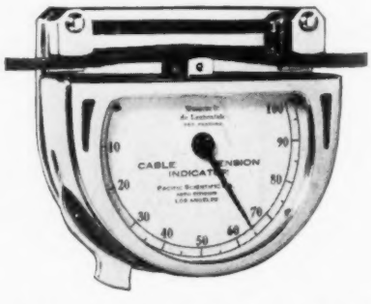
PHOTOVOLT CORPORATION
10 E. 40 STREET NEW YORK CITY
ELECTROCELL Photo-Elements, Colorimeters, Foot-Candle Meters, Exposure Meters.

Selenium Photocell

Selenium barrier layer photocell of a new type has been developed for light measurement and control. A special sensitizing process is said to give new cell high current sensitivity as well as high internal impedance. Units are said to be electrically stable and ruggedly constructed, are available in standard sizes or constructed to individual specifications. —*Bradley Laboratories, Inc., 82 Meadow St., New Haven, Conn.*

Cable Tension Indicator

New Sturgess Cable Tension Indicator was developed to fill need for a light, easily-handled instrument for measuring tension on aircraft control cables. It weighs



less than one pound; is said to be unique in that tension may be measured on cables of the following sizes—1/16", 3/32", 1/8", 5/32", 3/16", 7/32" and 1/4", through a range up to 250 lbs. This is accomplished by the use of risers of three different heights, each riser handling several sizes of cable, as specified on the instrument. Accuracy is said to be unaffected by temperature changes. Pointer may be locked in any given position, by means of a finger knob.—*Pacific Scientific Co., Bendix Bldg., Los Angeles, Calif.*

WHEATSTONE BRIDGE

A high-grade laboratory instrument containing 4 rheostat decades of 9 coils each, total resistance 9999 ohms, and a ratio dial affording 7 ratios, .001 to 1000. Rheostat coils are guaranteed accurate to within 1/10%, ratio coils to within 1/20%.

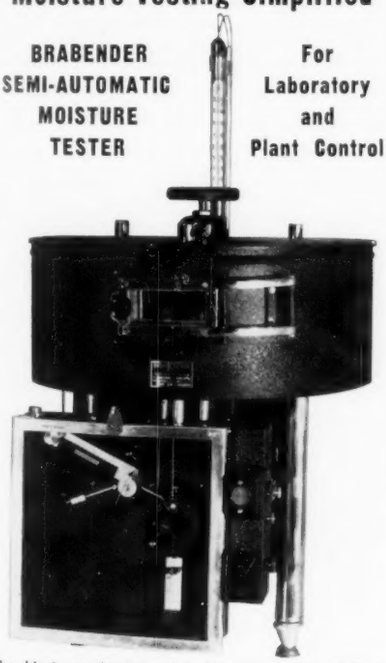
Described in Bulletin 100 which also describes Rubicon resistance standards, shunts, resistance boxes and several types of Wheatstone and Kelvin Bridges.

RUBICON COMPANY
Electrical Instrument Makers
29 North Sixth St. Philadelphia, Pa.

Moisture Testing Simplified

BRABENDER SEMI-AUTOMATIC MOISTURE TESTER

For Laboratory and Plant Control



An ideal combination of drying oven and analytical balance. Requires no training—just push down a lever and read the moisture loss from an illuminated dial—directly in percentages.

Accuracy—1/20th of one percent. Capacity—Ten 10-gram samples. Temperature Range—85° C.-175° C. Moisture Range—0%-100%. Heating Capacity—750 Watts. Operating Current—110 volts, 60 cycles, AC (25 cycles if required). Heating up time—5 to 10 minutes.

Write for pamphlet

BRABENDER CORPORATION Rochelle Park New Jersey

Continuous, Remote-reading Specific-gravity Indicator

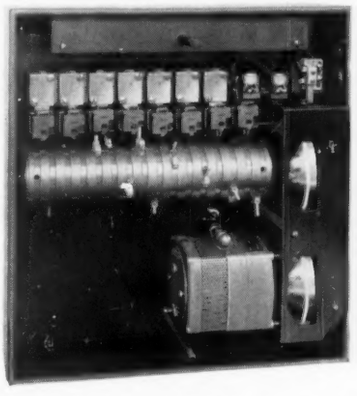
Novel method of determining fluid density utilized in new "Ashcraft Electric Hydrometer" permits extension of hydrometric measurements to numerous industrial applications where conditions preclude use of individual-sample methods. New automatic hydrometer consists of a vibrator unit and

For illustration, see maker's advertisement on this page.

an electrical measuring instrument. Vibrating element weighs approx. 1 oz., is energized by a few watts of 50- or 60-cycle a.c., may be lowered into tanks to depths as great as 50 ft., may be used where liquid is in motion or under moderate pressures, may be used also in semi-fluid masses such as cement slurries, oil-well rotary muds, etc. Electrical instrument regularly furnished is a 6" scale indicator graduated in lbs./ft.^{3}, °Bé, or other desired units of density or of specific gravity. However, connections are provided whereby recorders, controllers, etc., may be included in installation.—*Ashcraft Automatic Control Co., 127 Roycroft Ave., Long Beach, Calif.*

Sequence and Time Controller

Precise timing of sequence and duration of operations involving temperature, pressure, humidity or combinations of each, is purpose of new "Flex-O-Timer" which is



adaptable for all-electric, all-pneumatic operations, or combinations of both. Extreme flexibility is said to be obtained and cam cutting is eliminated by the use of adjustable pins on the revolving drum: pins fit in circumferential undercut grooves on the one-piece drum and are locked in place with a screw. Each air valve or switch can be turned on or off within 0.5% of total cycle time. A new latch-trip solenoid-operated mechanism starts process instantly. This actuates one or more snap operators to start the timer motor (high-torque fan-cooled synchronous type) and any outside electrical or pneumatic functions to be performed simultaneously at start of cycle. An external push button or limit switch can be used for this starting impulse. Where diversity of products being processed requires considerable variation in processing time, new Flex-O-Timer provides 78 different drum speeds with each gear train ratio. Drum speed is fixed for any given setting and can vary only as a-c supply frequency changes. Models are available also with a fixed-speed gear train. A new type low-leak air valve utilizes 99½% of the air passed through it. Air valve plunger is so designed that air supply port cannot at any time communicate with exhaust port, assuring rapid and full air pressure application and release. It is said that dirt particles are sheared off by close fit of piston, then exhausted from system, making new valve practically self-cleaning.—*Taylor Instrument Companies, Rochester, N. Y.*

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for the
continuous measurement of specific gravity

Utilizes a basically new principle of fluid density measurement by which the specific gravity of fluids may be instantly and continuously determined by immersion during the actual conditions of processing. Also may be used in closed tanks, vats and pipe lines, etc., while fluid is subjected to moderate heat, pressure, flow and agitation. Reads varying density in open tanks by immersion from surface to 50 foot depth. Wired for attachment to standard recorders and automatic density control equipment.

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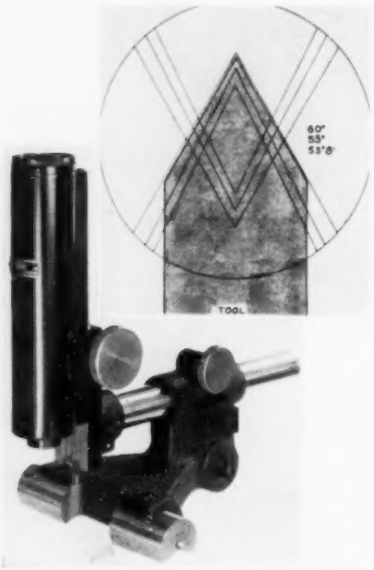
Optical Thread Tool Gage

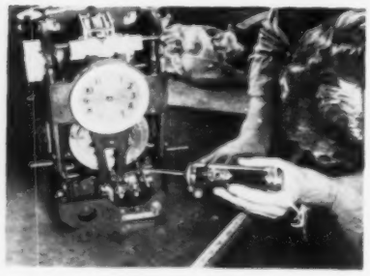
Rapid yet accurate set-up of single-point threading tools is said to be made possible by new Optical Thread Tool Gage which serves also for checking tool and thread



angles. Microscope has an unusually large eyepiece field of $\frac{7}{8}$" (in which appear characteristic angles of Am. Natl. Standard, Whitworth, and Metric threads), has rack-and-pinion focusing, is mounted on a keyed cross-rod which slides for adjustment in a reamed hole perpendicular to a mandrel in the base. Instrument makes possible setting up threading tool perpendicular to lathe center axis within 2 minutes of arc. Angle of tool itself is checked to same accuracy. To check thread angles on work, Optical Thread Tool Gage is simply placed on top of the work and cross-rod of instrument slid out until threads appear in field of microscope. Vee bottom of mandrel facilitates setting on work. Instrument is suitable for work from $\frac{3}{8}$" to $6\frac{1}{2}$" in diameter. Magnification is about 12×. A hardwood case is supplied.—*Gaertner Scientific Corp., 1211 Wrightwood Ave., Chicago, Ill.*

Flashlight Bulb Extension

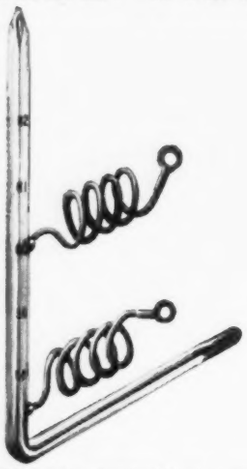
For inspecting and exploring the "innards" of instruments, meters and mechanisms, new Sierra Flashlight Bulb Extension can be introduced into a small opening ($\frac{7}{16}$"



min.) through any maze of wires or gears, behind or around equipment, and the bulb can be placed at the point desired. It is available in lengths from 6" to 36". At one end of the bendable tubing is a plug which will screw into any flashlight; at the other end a socket for the miniature bulb. Being bendable, the extension can go down into intricate mechanisms. It also can be bent into a hook for hanging, or can be fashioned into its own stand and set in position so that both hands are free to work.—*Sierra Aircraft Co., Sierra Madre, Calif.*

For Extremely Close Temperature Control

Visual-Stats



● Sensitivity of a hundredth of a degree is easily attainable. ● Top of mercury column visible at control point (where most important) because electrodes terminate at back of tube. No encircling metal bands! ● Available in angle form (illustrated) or conventional straight form. ● Send for brief, attractive bulletin.

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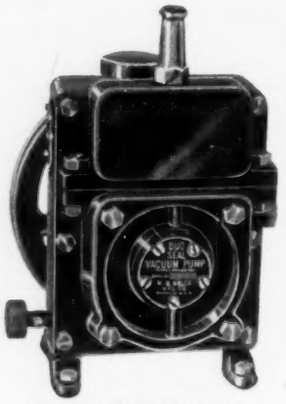

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Capacity—19 liters free air per minute. Vacuum—0.1 micron (.0001 mm Hg.) or better. Silent Operation. Positive Oil Seal—No oil can back up.

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Combustible Gas Indicator

New "Model 2 Explosimeter" combustible gas indicator incorporates advances in design and construction. Simplified electrical circuit features a single filament and single

control knob. One-hand operation leaves other hand free to handle sampling line or probe. Positive reading is obtained on second squeeze of bulb (5 ft. sampling line). Flow system is cast integral with case, and a built-in filter chamber is provided to trap dust and moisture. This filter chamber will also accommodate a charcoal cartridge for proper differentiation between illuminating gas and condensable combustible vapors such as gasoline. Explosimeter Model 2 is powered by standard flashlight batteries contained in a compartment separate from working parts. Hence, no exposure of working parts when batteries are changed; no possibility of electrolyte from discharged cells affecting electrical controls. Another feature is On-Off Signal Bar on single control knob, raised in view when current is turned on and flush with the knob when current is switched off, preventing user from unknowingly leaving instrument with current on. Replaceable single filament has a normal useful life of several thousand tests; a spare contained in case is ready for instant use.—*Mine Safety Appliances Co., Braddock, Thomas and Meade Sts., Pittsburgh, Pa.*

Voltage Regulating Transformers

Design changes featuring new line of "UTC Varitran" units are said to enhance their ruggedness and reliability. In addition to glass-insulated wire throughout all

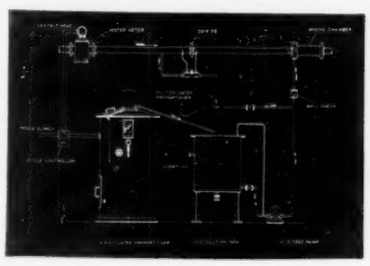
sizes, multiple-contact units now employ ballast coils to assure uniform contact loading. Varitran units are available for 115- or 230-volt service with respective output voltages of 0-130 and 0-260 volts. Smooth non-interrupted control is said to be effected in all sizes from 2-amp. "Model V-0" to 44-amp. "Model V-7."—*United Transformer Corp., 150 Varick St., New York, N. Y.*

Potentiometer Pyrometer

A single electrical-instrument movement of "Model 50-MPO Mono-Potentiometer" serves both as a galvanometer and the temperature indicator, the two functions being combined in a novel circuit said to enable temperatures to be "accurately measured by use of thermocouples substantially independent of circuit resistance." Other features include simplicity of controls and compensation for cold-junction error and copper error of the instrument. Power for operation of the instrument by the potentiometer principle is derived from two small dry cells. Instrument circuit is said to be so arranged that the voltage of these dry cells does not affect calibration. Current consumption from the cells when in use amounts to less than 2 ma. To operate, pointer is checked for zero as indicated by a red line on the scale. (If necessary, zero adjusting screw is used.) Thermocouple is attached and current turned on with switch "BA." Operator then depresses push button switch marked "SW," and rotates rheostat knob marked "BAL" until pointer stands at red zero line. He then releases push button switch and reads temperature. To verify a temperature reading, depress push button switch: if pointer remains on zero, no balancing is necessary as temperature shown is same as when last read: otherwise, the "BAL" knob is turned, the "SW" released and the new temperature read. When instrument is not in use, the "BA" switch is turned to "Off." New Mono-Potentiometer is available with 3⅛" scale in ranges 0-400, 0-650, 0-1200 and 0-2000°F. It is designed as a potentiometer for laboratory and industrial use to give independence of thermocouple condition, length, or cross-section (within wide limitations) while retaining the ruggedness of a medium-resistance instrument.—*J-B-T Instruments, Inc., 441-H Chapel St., New Haven, Conn.*

Proportioning Equipment for Corrosive Fluids

New Air-actuated Proportioner was designed especially for accurately feeding sulphuric acid in conditioning boiler feed water. A contact meter in series with a cycle



controller operates an air compressor inside the proportioner shell when a predetermined flow is reached. The acid is measured into the dilution tank to which dilution water is proportioned by a mechanism that prevents too high or too low chemical concentration usually associated with batch feeding. A special feed-line fitting provides for proper introduction of diluted acid or other fluid into the main flow. New Proportioner is suitable also for proportioning any corrosive solution, such as aluminum sulphate, ferrous or ferric sulphates, etc.—*Cochrane Corp., 17th & Allegheny Ave., Philadelphia, Penna.*

The DECADE BOX

that handles power . . .

Covers resistance range of 1 ohm to 999,999 ohms, at voltages up to 1000 max.

★

Each decade dissipates up to 225 watts. GREENOHMS (wire-wound cement-coated power resistors) used throughout. Glass-insulated wiring.

★

Six decade switches on sloping front panel.

★

Max. current per decade: No. 1, 5 Amp.; No. 2, 1.5 Amp.; No. 3, .5 Amp.; No. 4, .15 Amp.; No. 5, .05 Amp.; No. 6, .005 Amp.

★

Handsome frosted-gray metal case. Etched black and aluminum panel. Dual input binding posts, for left and right-hand duty.

★

Grille at bottom and louvres at side for adequate ventilation. Baffle plate protects switch mechanism from heat.

★

Measures 13" long x 8½" deep x 5¾" high. Weighs 11 lbs.

★ From "The House of Resistors" comes the very thing you laboratory workers and engineers have been waiting for—the Clarostat Power Resistor Decade Box. Handles real Power. Simplifies and expedites selection of correct resistance values for any circuit or working condition. A handsome instrument truly worthy of a place in every well-equipped laboratory or engineering department.

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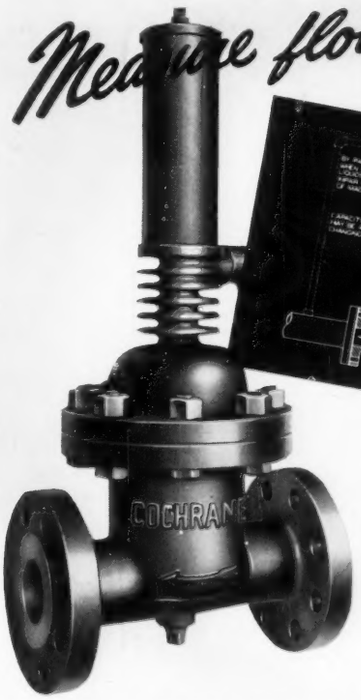
Measure flow of **OIL · TAR · AMMONIA** *accurately*



COCHRANE LINAMETER

The Cochrane Linameter is designed to measure the flow of those fluids having characteristics of viscosity, corrosiveness or solubility, such as fuel oils, ammonia, tar, sulphuric acid, or caustic soda, which have been previously difficult to measure accurately.

Its absence of U-tubes and diaphragms and its short float travel make the Linameter an extremely sensitive instrument of measurement.

Write for Publication 2100 listing 15 practical advantages of this new meter.

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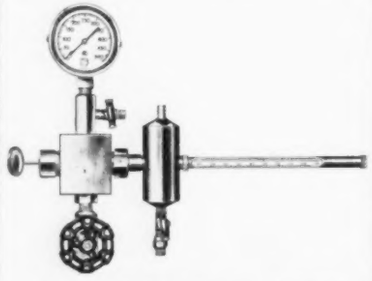

DEW POINT TESTER

FOR HIGH PRESSURE GASES

Bureau of Mines Type

Simple to operate and accurate in results.

This apparatus for the accurate determination of the dew point of gases under pressure was developed by the Bureau of Mines and is described in its Report of Investigations 3399.

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SIMPLEST AND MOST EFFICIENT

Bulletin 504

THREE DIFFERENT STYLES

Portable Standard with single electrical zero return.

Switchboard Type with above zero feature located on flexible lead for bench operation. Two Button Pointer Shift in place of our patented standard zero return at a lesser cost.

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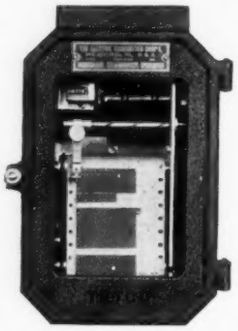

Creates a permanent time record on a waxed chart. Accurately records rate of production, time and duration of stops, total quantity produced.

The Electric Tachometer Corp.
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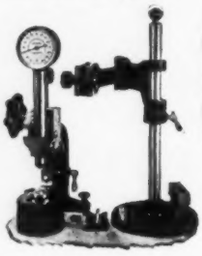
done WITH NO MENTAL HAZARDS. The SCLEROSCOPE has done it for the past 30 years.



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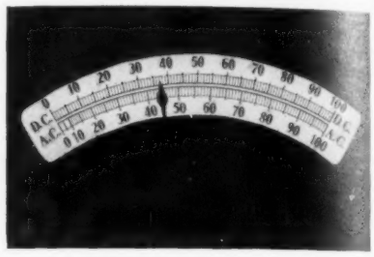
RHEOSTATS

Ask for Catalog No. 5

National Electric Controller Co.
5317 Ravenswood Ave., Chicago, Ill.

Projection Instrument and Range Selector

Illustration shows a typical image obtained on screen with new "Model 525 Projection Instrument"—not instrument itself. Chief purpose of new device is to provide



large indications visible to lecture-room audiences; other applications are routine testing, technical displays, etc. Basic instrument, with a maximum of three self-contained ranges, can be used for direct measurement of d-c. currents up to 100 ma. and d-c. voltage up to 150 volts. Further extension of these ranges can be obtained through use of external shunts and multipliers. Special scales can be supplied for measurement of resistance, capacity, noise or volume levels, and other specific applications. "Type 12" universal instrument, when used in conjunction with the "Model 9964 Range Selector," provides 30 a-c. and d-c. current and voltage ranges. In addition, basic instrument can be used in conjunction with thermal converters for measurement of a-c. current at any frequency; with copper-oxide rectifiers for measurement of a-c. voltage; with thermocouples or in a resistance bridge for temperature indication; with current or voltage generating devices such as photocells, small generators, etc., for measurement of foot-candles, r.p.m., f.p.m., etc. Model 525 consists of a permanent-magnet moving-coil instrument mechanism mounted in a cast aluminum housing $4\frac{3}{8}$" high, $1\frac{5}{8}$" thick and $9\frac{3}{4}$" long. Any projector which will accommodate a slide holder $1\frac{5}{8}$" thick and $4\frac{3}{8}$" high will be satisfactory. For most work, images of 3 to 6 feet will be possible with normal room illumination. Sides of instrument housing incorporate cooling fins for the dissipation of heat under normal conditions. (A special projector, incorporating a fan for additional cooling, is available.)—*Weston Electrical Instrument Corp., 591 Frelinghuysen Ave., Newark, N. J.*

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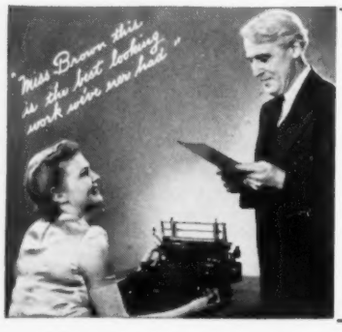
(1) articles on photography—new amateur gadgets, new devices amateurs can make themselves
(2) articles on homecraft
(3) articles on Popular Science
(4) articles on new instruments of any description.

Box 50, INSTRUMENTS PUBLISHING CO., 1117 Wolfendale Street, Pittsburgh, Pa.



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Application of Automatic Control Instruments to Diesel Engines

By GEORGE B. BAILEY

President, Thermal Engineering Co., Boston, Mass.

Awarded a Fourth Prize in the First Annual Instrumentation Contest

INTELLIGENT application of automatic recording and controlling instruments to the Diesel engine may well play a most important part in its future development, as it has in the past for the oil-burner, air-conditioning, refrigeration and other industries. This forecast is based on the results obtained in applying control instruments to several Diesel power installations in recent years.

Until a few years ago the heavy, slow-speed Diesel engine was the only type available. The builder of this type of engine had developed an excellent and dependable, although rather expensive and inflexible unit. Over a period of four or five decades, little headway had been made in its application to other than made-to-order power problems. If any degree of flexibility was required, due to varying load conditions, or if even a reasonable stand-by capacity were important, the slow-speed Diesel engine did not fit into the picture because of its high first cost and its poor efficiency under low-load conditions.

The standardized multi-cylinder type of Diesel engine developed for the transportation field seemed to overcome many of the objectionable features of its slower speed predecessors. Its governed speed was adjustable over a wide range and its operation was smooth and vibrationless over the full speed range. Its electric starting equipment was adaptable for remote and, therefore, automatic control. Its light weight eliminated foundation problems, and its first cost was reasonable because of production methods.

Not only was the higher speed Diesel far more flexible than its predecessor, but applied to loads within its capacity it soon proved itself to be equal in efficiency and general performance. But here, too, its use seemed to be limited to application to loads within its capacity because, although it had long been recognized that multiple-unit application would be extremely advantageous, there were mechanical and electrical complications to be overcome before multiple operation in parallel was practical.

It became increasingly apparent that multiple application of the standardized higher speed engine offered the best solution for many power problems, particularly so with alternating-current generating plants. It only remained to develop a control that would regulate the loading of the individual units, prevent "hunting" of the governors, and simplify the synchronizing problem so that little or no manual attendance was necessary. This at first seemed to be quite an order but the solution proved to be a straightforward application of standard control instruments.

The a-c. generating plant problem which not only precipitated the use of the standard control instruments but led to the development of a fully-automatic power plant, was one to which the application of four engines was obviously the best solution. It was decided that in order to cut down electrical complications, only two alternators would be used, these alternators to have double-extended shafts for receiving drive, through clutches, from each end by one of the four Diesel engines.

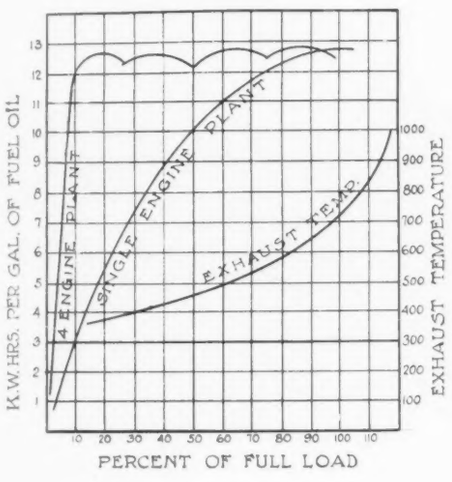


Fig. 1

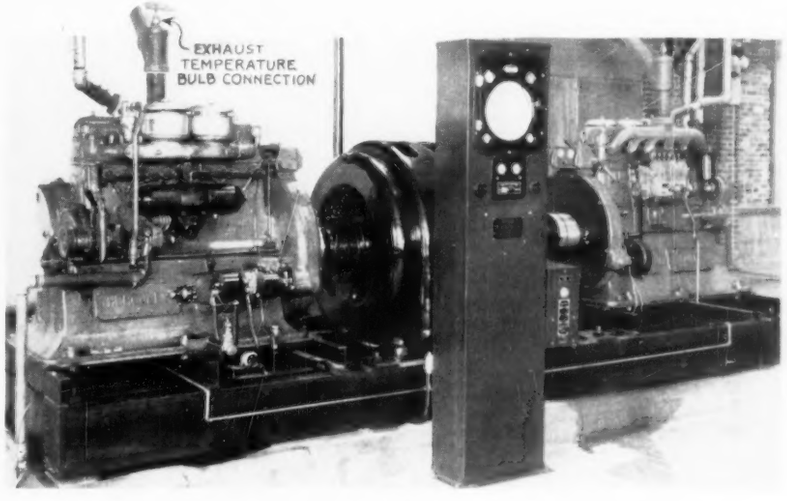


Fig. 2

The generator manufacturer cautioned that parallel operation would not be satisfactory unless the governors of the engines were tied together or controlled in some manner. This led to a careful consideration of all the factors involved, one of which soon stood out as being a logical control medium for an internal combustion engine; i.e., the exhaust temperature; because it is at all times a close indication of the load as shown in Fig. 1.

The idea of using the exhaust temperature for control purposes was the nucleus of what finally became a fully-automatic multiple-unit Diesel electric generating plant. It had been considered not only important but absolutely necessary to divide the load evenly between the various prime movers or units when operating in parallel. The reason for this was to prevent any unit from taking more than its share of the load, or overloading, and to prevent cross-currents that might flow in the event that one of the prime movers should be driven by the others, etc.

Because the loading on any one of the prime movers was reflected by its exhaust temperature and, therefore, could be controlled, it was decided to break precedent by loading one engine up to the point of maximum efficiency, before starting to load the next unit; and so on. Due to experience with the same instrument in the drying and

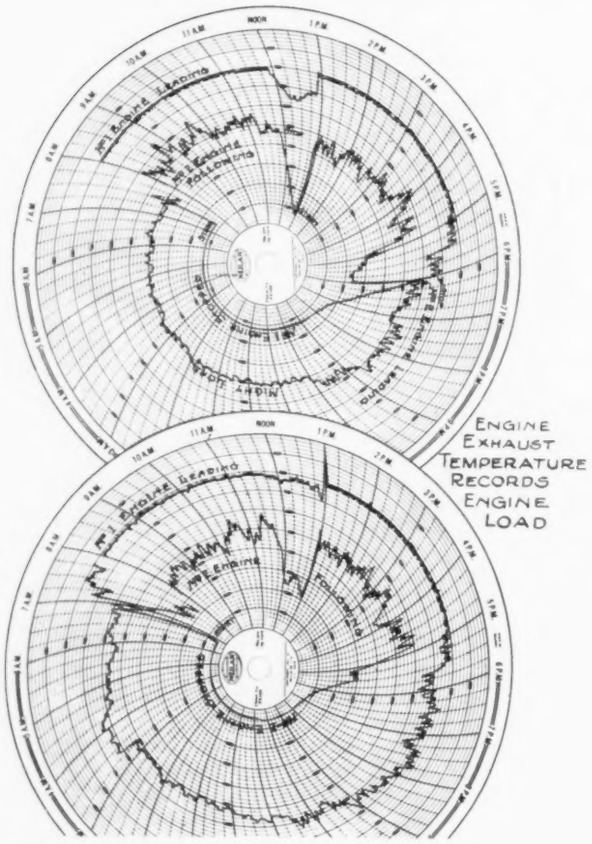


Fig. 3

air-conditioning fields, it was only natural that the air-operated recorder-controller was chosen as the control instrument. Results have proven that this highly-developed industrial instrument lends itself perfectly to this application.

The first commercial installation was a plant similar to Fig. 2. It consisted of a double-ended alternator connected through overrunning clutches to the two Diesel engines. These clutches allowed either of the engines to operate and to be controlled independently of the other. A dual type air-operated temperature recorder-controller, with a range of 0-1000°F., was built into a cabinet along with other supplementary instruments. Two stainless steel bulbs, one for the exhaust of each engine, were used, along with sufficient cable length to provide for locating the cabinet at a convenient point adjacent to the unit.

The unit was a success right from the start. Typical daily charts are shown in Fig. 3 and serve to illustrate the excellent control that is obtained. Manual attention is practically eliminated except for a routine daily inspection.

Exhaust temperature records serve as exact daily logs of each engine operation and reflect every load change. As indicated, there is a 24-hour load on this plant. During the night there is only sufficient load for one engine, the other remaining idle. Just before 8:00 a.m. the load on the leading or continuous-running engine results in the exhaust temperature reaching the control point, at which time the second or following engine is automatically started and controlled. Both engines are required for the day load, although occasionally the second engine drops out at noon-time.

It is to be noted that load on the continuous-running or leading engine, as reflected by its exhaust temperature, remains constant during the period that it is controlling the following engine, the torque exerted by the latter taking up all of the variation in the load. This results in a practically constant speed, whereas if the two governors were operating independently as has been the practice, there would be constant variation in the speed with every variation in the load.

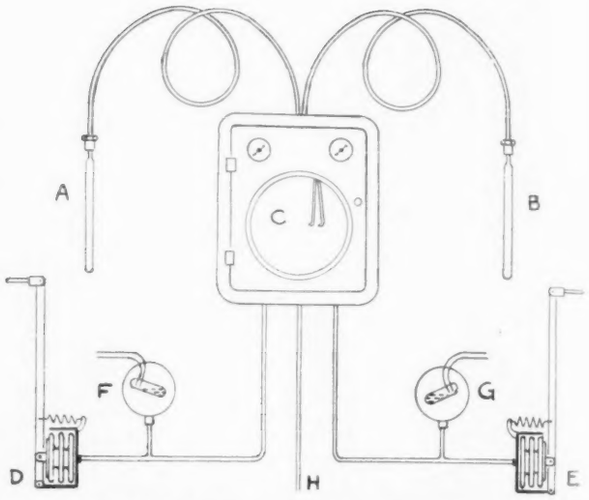


Fig. 4. A, B—Exhaust temperature bulbs; C—Dual type temperature recorder-controller; D, E—Diaphragm motors commanding engine governors; F, G—Pressure switches to engine-starting motors; H—Air supply.

The general arrangement of the control system is shown in the diagram, Fig. 4. Pneumatic switches marked "lead" and "follow" are provided, by means of which either of the two engines can be the leading engine, with the other engine following. The diaphragm motors are connected to the governor adjustment lever, through which the torque exerted by the following engine is controlled by the exhaust temperature of the leading engine. Each engine is equipped with a 24-volt electric starting system which is arranged for automatic starting through a simple pressure switch, also actuated by the controlled air pressure from the main controller.

This type of control, in a modified form, has been applied to a number of different problems since the original installation. An automatically balanced steam and Diesel unit has been in operation for over two years, in which the exhaust temperature recorder-controller was supplemented by a standard pressure controller. Another installation involved an automatic Diesel pumping unit, Fig. 5, where both capacity and pressure were controlled. Also, another modified application of the recorder controller to a direct-current generating plant has resulted in even more flexibility, in that not only do the various units start and stop as required, but their speed also becomes a function of the load. In fact, the potential field for this and other control instruments applied to Diesel and gas engines seems to be unlimited.

There is practically no limit to the number of the standardized Diesel or gas engines that may be operated coöperatively in parallel, with perfect assurance that little or no

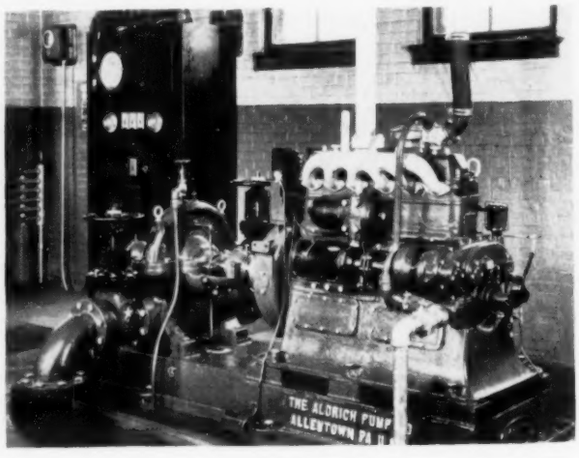


Fig. 5

manual attention will be required by this relatively simple application of standard instruments. Such a plant offers the maximum in flexibility, efficiency and reliability, along with minimal first cost, maintenance and attendance.

Therefore, the multiple-unit Diesel power plant may well be the Diesel power plant of the future, in which case automatic control instruments must necessarily play a most important part.

Steam-engine Indicator Adapted to Record Differential Pressure

By WILLIAM B. HESS

Test Engineer, Safe Harbor Water Power Corp., Conestoga, Penna.

Awarded a Fifth Prize in the First Annual Instrumentation Contest

A STEAM engine indicator converted to record differential pressure is described herein. The pressures exceeded those normally encountered in the use of standard differential pressure instruments.

The necessity for this particular device arose when investigations were under way to find the forces required to operate the runner blades of a Kaplan turbine under conditions of sudden load application and rejection. The blade-operating servo-motors are 68″ in diameter, stroke 11.5″. These servo-motors control the pitch of five blades of a Kaplan turbine runner 220″ in diameter, rated at 42,500 h.p. under 55′ head.

The fluid medium is oil under a pressure of 200 lbs./in.^{2}. At times, the maximum differential may equal this value, therefore this possibility eliminated the use of standard differential gages then available. No instrument for recording differential pressures up to 200 lbs./in.^{2} could be found at that time. The pressure phenomenon that occurred during these tests was too fast to accurately determine identical points when using individual pressure instruments on each side of the servo-motor piston. Several different methods along this line were tried, as follows: (1) two ordinary Bourdon tube gages; (2) two separate steam engine indicators; (3) two recording pressure gages. In all of these methods one instrument was connected to the side of the piston requiring pressure to open the blades, the second instrument being connected to the opposite side: that requiring pressure to close the blades.

After the above-mentioned methods failed to give the required information, one steam engine indicator was altered so that differential pressure across the piston was recorded on the regular indicator card inserted in the usual manner on the card drum. This conversion was made in the following manner: The existing drain holes that normally carry away leakage past the piston were closed; the top section of the cylinder was drilled through and tapped for a pipe connection; a small packing gland was installed around the piston rod to reduce excess leakage and this gland was adjusted to minimize friction on the rod. With this arrangement it was possible to admit pressure to both sides of the indicator piston. The instrument was mounted on a steel block so constructed that tubing or pipe connections could be made easily. (See Fig. 1). As an additional feature, a small solenoid and pen were attached to record one-second impulses from a contact timer.

The gage was calibrated by means of two Crosby gage testers. Naturally the piston rod on one side of the indicator piston reduces the area and hence the pressure reading. However, when used on tests, two identical runs were made on each test, the pressure connections being reversed on each run.

For this investigation the gage was mounted at a location such as to have a minimum amount of piping and still be in a position to readily attach a cord to produce travel of the indicator card drum. When measuring blade servo-motor pressures the gage is mounted on the Kaplan head. From this location a short and simple piping arrangement is required and drum travel is obtained by passing the cord over a sheave mounted on the blade position indicator shaft. A test set-up is shown in Fig. 2.

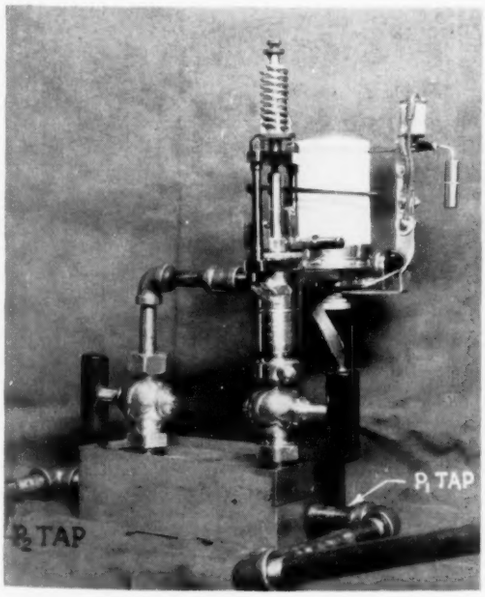


Fig. 1

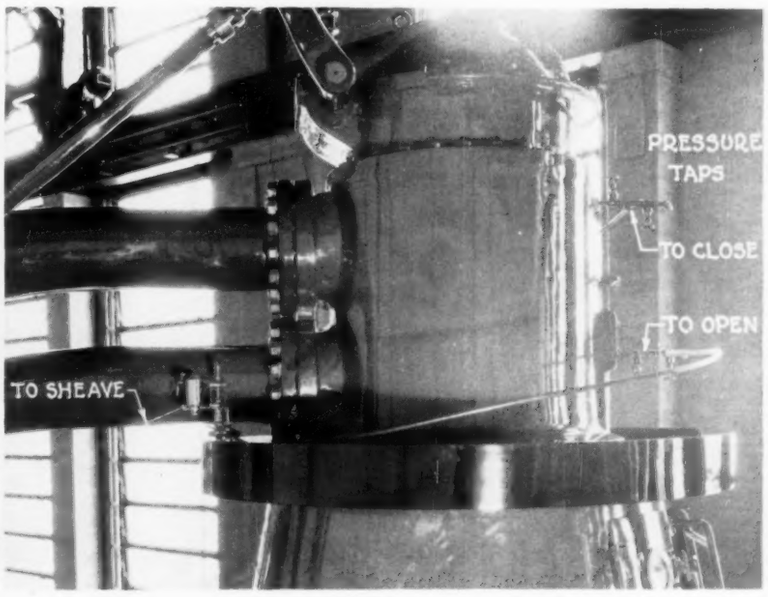
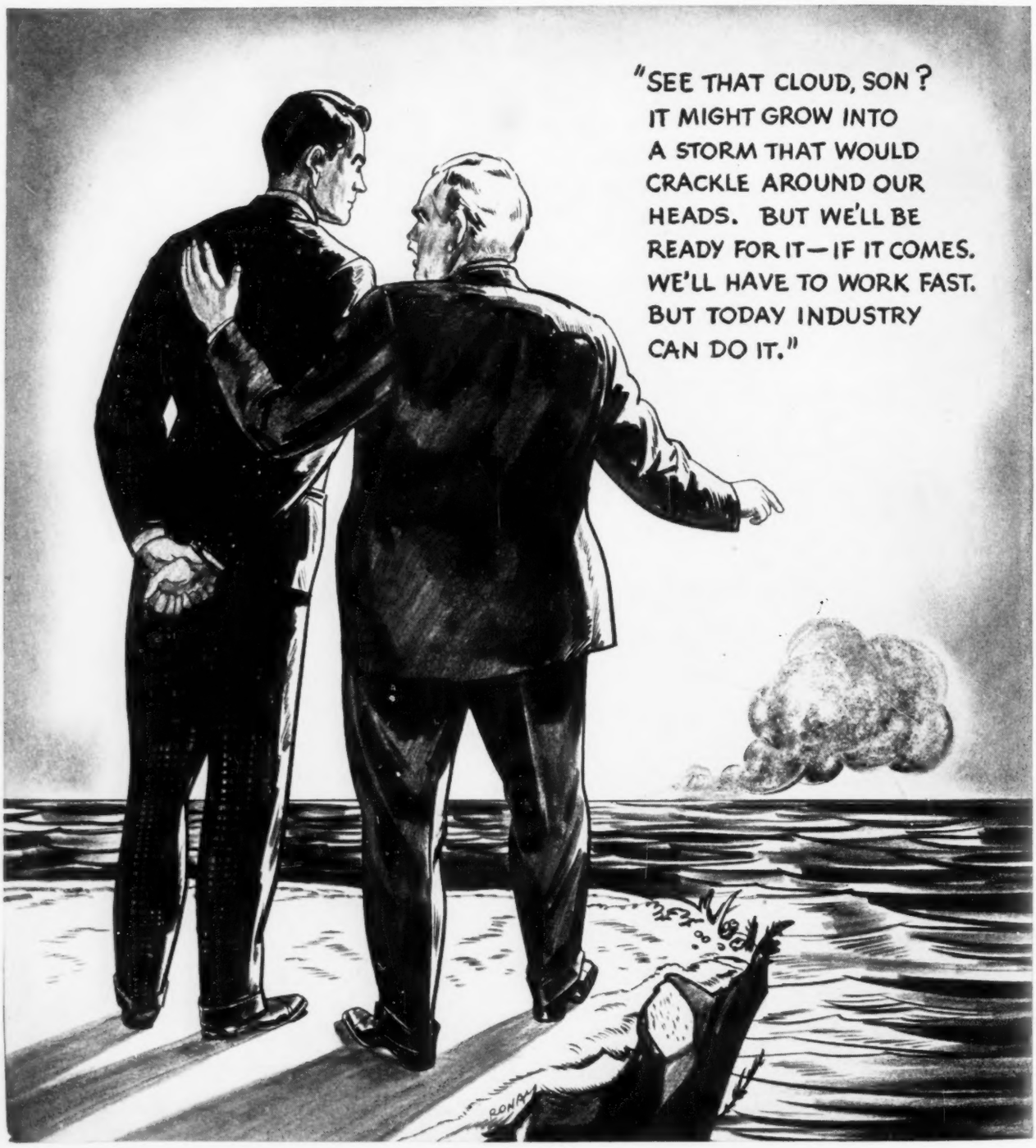


Fig. 2

"WE WILL PREPARE,"

"WE WILL HELP YOU


"SEE THAT CLOUD, SON? IT MIGHT GROW INTO A STORM THAT WOULD CRACKLE AROUND OUR HEADS. BUT WE'LL BE READY FOR IT—IF IT COMES. WE'LL HAVE TO WORK FAST. BUT TODAY INDUSTRY CAN DO IT."

says American Industry

PREPARE FASTER," *says Taylor*

Today's industry can do its bigger job of national preparedness faster than industry of a generation ago could hope to—with the aid of Taylor Instruments which today provide precision control that was not possible then

AMERICA'S Peace and Security Must Not Be Endangered! You, and you, and you—makers of machines, weavers of textiles, canners of food, providers of power—must be prepared. You are America's defense. You must be ready for faster, larger production. You must be ready for more efficient, economical operation of your plants and factories. Our national need is speed.

In a similar crisis, a generation ago, Industry carried out a great preparedness program successfully. But it was not easy. It took too long.

Today, Industry's shift into high gear should be far easier and faster than it was twenty-odd years ago. For instance, American Industry today has the help of many Taylor Instruments that were not available in those days.

For much has been happening at Taylor Instrument Companies in the years since that last time Industry was called upon to "Be Prepared!" Taylor research engineers have been busy. With the experience of almost ninety years of instrument-making to guide them, they have perfected instruments before thought impossible.

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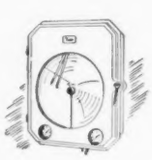
Take the amazing new Taylor Fulscope Controller as only one outstanding proof. It's a completely new instrument for *all* industry. It helps to make the operations in *your* plant—whatever you manufacture or process—as exact, as foolproof as scientifically possible. The Fulscope Controller stands constant guard—controlling, recording, preventing slips or sloppiness. Its unique range makes it actually *five controllers in one*—a multi-use efficiency expert without human failings.

And the Taylor Fulscope Controller is only one name on the Taylor roll-call of instruments to help Industry. No need to list all the others here. Some of the most useful have been specifically created for the particular requirements of particular industries. Your own industry, perhaps. All of them have been designed with a single purpose: better, faster, industrial production at lower costs.

Preparedness can't wait. This country can't afford industrial log-jams. There's a huge job to do, and it must be done *now*. Taylor Instruments will help to see that it *is* done . . . Taylor Instrument Companies, Rochester, N. Y., Toronto, Canada, and London, England.



Taylor

Indicating Recording · Controlling

TEMPERATURE, PRESSURE, FLOW *and* LEVEL INSTRUMENTS

A Sensitive Method of Flow Control

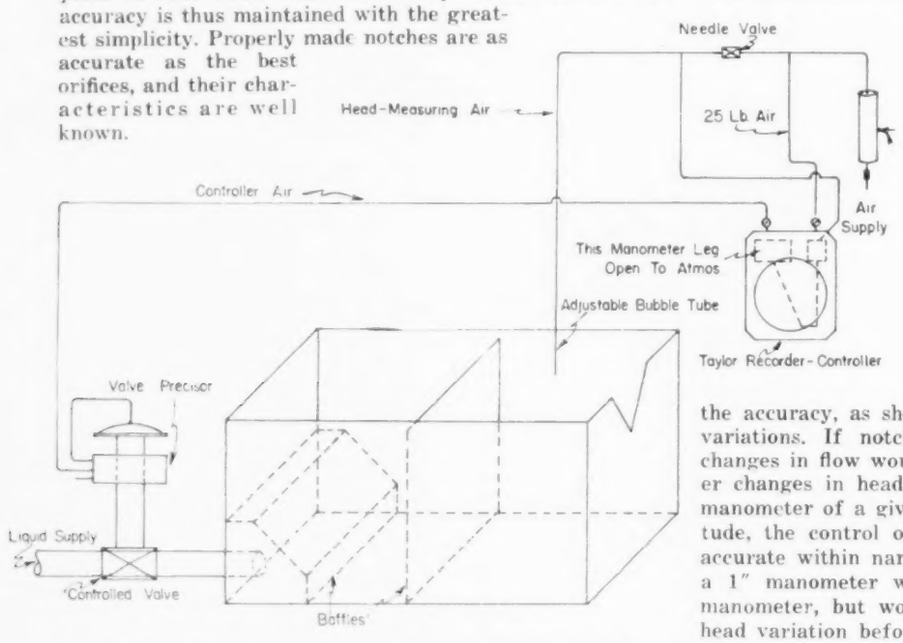
By M. G. MASTIN

Chemical Engineer, Westvaco Chlorine Products Corp., South Charleston, W. Va.

Awarded a Fourth Prize in the First Annual Instrumentation Contest

EASE in operation of a new Pacific Coast plant for the production of magnesium oxide from sea-water bittern* depends to a considerable extent on having available means for closely controlling the flows of the various brines which serve as raw and process materials. The apparatus finally adopted after several experiments so well serves the purpose that it seems worthwhile to describe it briefly, especially as the accuracy of the method considerably exceeds that obtainable by the usual methods of flow instrumentation.

The four brine flows and one water flow involved vary from 100 to 500 gallons per minute depending on production rates and are therefore large enough to require rather expensive meters of the displacement type. Furthermore, as no brines are free from small amounts of suspended matter, such meters require frequent cleaning in order to maintain their accuracy. Orifice meters are subject to the latter objection also, and although there are now orifices that can be cleaned without removal from the flanges, it was decided to use weirs with V-notch orifice plates for the measurement of the various flows. The V-notch has the advantage of being visible, for inspection, and is also readily cleaned by wiping with the finger or a piece of soft wood without interruption of the flow. Its accuracy is thus maintained with the greatest simplicity. Properly made notches are as accurate as the best orifices, and their characteristics are well known.



It had originally been planned to use level recorders as flow-meters, only, in the usual manner with V-notch meters, but investigation revealed the possibility of controlling the flows as well as metering them. Several instrument companies would guarantee to maintain levels, but not within limits closer than $\pm \frac{1}{8}$", whereas, in order to get an accuracy of $\pm 1\%$ in flow at 200 g.p.m. over a 90° notch, we needed to control our level within a range of about 0.025". Floats linked with the inlet valve were tried, but it was found that small changes in liquid level above the notch were insufficient to overcome friction. Finally, it was found possible to measure extremely small level changes by measuring the pressure necessary to bubble a small stream of air below the liquid surface; and it was then but a short step to apply to the system a standard air-operated controller, a low-range manometer as its measuring element, as shown in the accompanying diagram.

Liquid flow is through the controlled valve to the weir tank where it passes through perforated plate baffles to smooth out turbulences, and then over the measuring notch. The bubbler tube extends under the surface of the liquid and is adjustable vertically in increments of 1.50" by a clamping device not shown in the drawing. At its lowest position it is exactly 1.50" above the apex of the V-notch. The head required to bubble air through the liquid is also applied to the right-hand leg of the manometer in the controller, the other leg being open to the air. If this head varies, the controller operates to shift the valve position in a direction which will correct the change. The amount of air to the bubbler tube is controlled by the needle valve to a flow of two or three bubbles per second. The bubbler tube is ¼" O.D. copper tubing cut off square at the end, and is maintained in a vertical position. If turbulences of the liquid surfaces are encountered, as from surging or wind, a stilling well around the bubbler tube would be helpful.

Accuracy—The chart used has a 5" scale, reading from 0 to 2.5" of water column. Each scale division measures 0.1" and corresponds to 0.05" of water column. The pen normally makes a line about 0.012" of water column wide, if that term may be used, but at times when the pen is nearly dry, and a fine line is being drawn, it is evident that control is being had within about 0.005" of water column. With a 90° notch, when $h = 6.0$" the flow is 200 g.p.m., and each 0.005" change corresponds to slightly less than 0.5 g.p.m. The flow at this level, therefore, is being controlled with an error of about 0.25%. At smaller heads the error is less and at larger heads it is greater. Pressure changes in the liquid supply line do not appear to affect the accuracy, as shown by hook-gage check tests on level variations. If notches less than 90° were to be used, changes in flow would be accompanied by relatively greater changes in head, but as the control of the head by a manometer of a given range is always of the same magnitude, the control of flow over a narrow notch would be accurate within narrower limits. Also, with a given notch, a 1" manometer would give closer control than a 2.5" manometer, but would control over a narrower range of head variation before the pen would get off the chart.

Dependability—Aside from failure of the air supply, there is not much chance of control failure. The brines on which these meters are used are slightly under-saturated, but nevertheless, a deposit of salt gradually builds up in the bubbler-tube in such a way as to restrict the opening. If allowed to continue, this stoppage acts as an increase in level and the diaphragm valve gradually closes until flow ceases without giving any chart indication of this condition. This is overcome by running a wire up the bubbler-tube once a day, as a matter of routine at the time the charts are changed. It has also been found advisable to flush the valve-body with water about once a week, because with steady flows there is little valve movement, and salts tend to accumulate around the moving parts. With water flows, neither of these precautions is necessary.

Flexibility—It is obvious that this method of flow control can be applied to nearly any liquid flow that can be handled

*Residual brines from the crystallization of salt from sea-water by solar evaporation.

in a weir, no matter what the size. Manometers are commonly made from a range of 100″ down to 1″ of water column, and there is no reason why a range of 0.1″ could not be used, if desired. Notches of any angle or shape, or even multiple notches in one weir, can be employed. If a parabolic notch is used, inches head is directly proportional to gallons flowing.

Sensitivity is also adjustable over wide limits—a desirable feature. Although all five weirs are the same size and design, and have the same baffles for prevention of turbulence, it was necessary to vary the location of the bubbler-tubes with relation to the inlets in some cases. It was found that two of the weirs were particularly liable to start surging, but this was remedied in a moment by decreasing the sensitivity from "Low *F*" to "Low *H*." No apparent decrease in accuracy resulted.

Change of flow is readily obtained by changing the control point at the instrument. Response is immediate, and if sensitivity is correctly adjusted, there is no, or very little, hunting. If the new flow is outside the chart range, the bubbler-tube is adjusted to the next higher or lower position, as the case may be, and this fact is noted on the chart for completion of the record.

Summary of Advantages—(1) Accuracy of measurement and control better than by usual methods. (2) Cost of control installation moderate, and for our flows, less than would have been paid for displacement meters without any control equipment. (3) Controller is air-sealed from controlled liquid, thereby preventing corrosion of instrument. (4) Rate of flow changed by resetting a knob in the instrument. (5) Accuracy of metering device (the notch) readily maintained without interrupting flow. Condition of notch visible at all times. (6) Applicable to liquids of any temperature below their boiling points, and to liquids whose viscosity is at least 10 times that of water. (7) Apparatus is simple and easily understood. (8) Practically no limit to the rate of flow that it is desired to control. (9) Controller can be placed at a point remote from the weir and either above or below it.

Acknowledgment—Credit is due to the Taylor Instrument Companies and to Mr. J. E. Philpot of the Taylor Instrument Companies for their ready aid and coöperation in working out the details of this application.

Remote-control Instrumentation

By F. ROONEY and C. ROMANO

Westvaco Chlorine Products Corp., Newark, Calif.

Awarded an Honorable Mention in the First Annual Instrumentation Contest

UNUSUAL problems called for unique methods of instrumentation in the design of a new plant for processing sea-water. The near saturation saline characteristics of concentrated sea bittern made the use of any ordinary type of liquid meter definitely impractical both from the standpoint of accurate processing as well as continuity of flow. One problem was essentially as follows (refer to the accompanying schematic flow sheet):

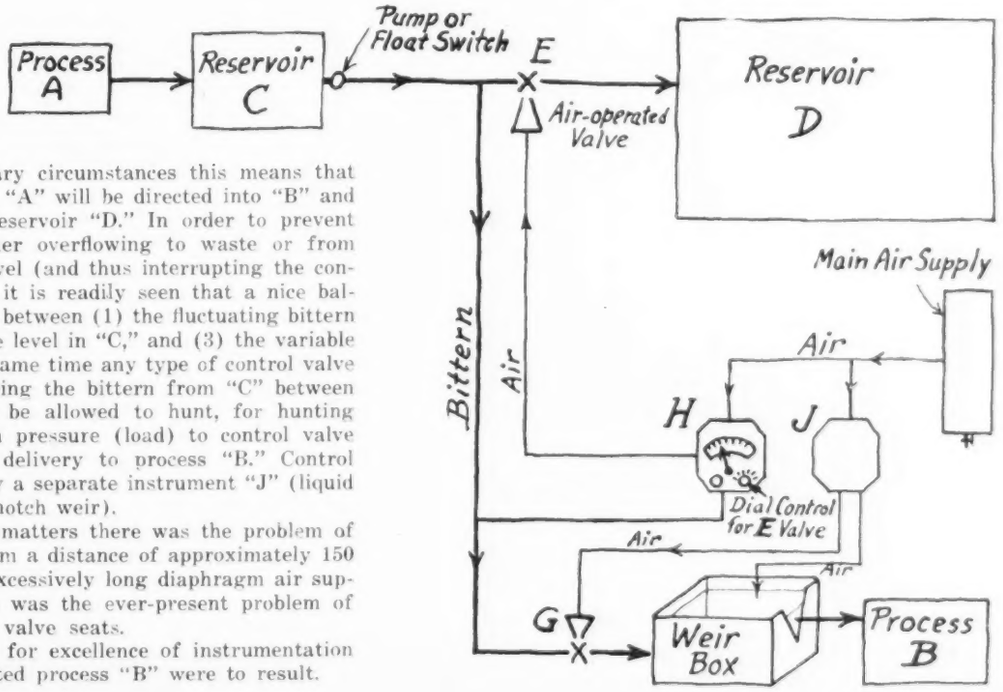
Bittern from process "A" is run into a pond reservoir "C" of limited capacity, thereby temporarily retaining a desirable heat content. If not used within the time limit of its capacity, it is automatically pumped into a much larger reservoir "D" with a consequent loss of available heat content. Process "B," which is inoperative part of the time, uses as much bittern from "A" as is commensurate with its desirable heat content and certain other undesirable characteristics. Under ordinary circumstances this means that part of the bittern from "A" will be directed into "B" and the rest diverted into reservoir "D." In order to prevent reservoir "C" from either overflowing to waste or from dropping to too low a level (and thus interrupting the continuity of process "B"), it is readily seen that a nice balance must be maintained between (1) the fluctuating bittern supply from "A," (2) the level in "C," and (3) the variable demands of "B." At the same time any type of control valve "E" splitting and balancing the bittern from "C" between "B" and "D" must not be allowed to hunt, for hunting would cause variation in pressure (load) to control valve "G" regulating volume delivery to process "B." Control valve "G" is regulated by a separate instrument "J" (liquid level control to a 90° V-notch weir).

To further complicate matters there was the problem of controlling valve "G" from a distance of approximately 150 yards, necessitating an excessively long diaphragm air supply line; and then there was the ever-present problem of saline deposition in the valve seats.

These problems called for excellence of instrumentation control if an uninterrupted process "B" were to result.

The type of control system finally worked out is shown in the accompanying diagram. It consists of a Taylor "Fulscope" indicating controller "H" and a diaphragm valve "E" with a "Valve-Precisor" and single response. It was not necessary to have a recording system since the level in reservoir "C," which is, of course, a function of the amount of diaphragm valve opening "E," is visible from process "B." Thus, the level in "C" is held within tolerance limits by means of controller "H," which in turn does not create any violent fluctuations in pressure (load) to control valve "G" regulating volume flow to process "B." Disregarding the impracticality of any type of manual control for such a process, one can imagine the amount of footwork saved in periodic 150-yard sprints to the splitting Y.

A large range of sensitivity adjustment on the controller "H" enabled us to find the best instrument control point



for balancing "C," "B," and "D," and at the same time synchronize with the control point setting of controller "J."

The performance of the "Valve-Precisor" on control valve "E" proved to be satisfactory under conditions which were known from long experience to be extremely difficult on all types of bittern line constructive devices. The "Valve-Precisor" enables the diaphragm to command the entire air line supply pressure, if necessary, to correctly position the control valve. This is necessary where saline deposition builds up on the valve parts. The control valve as installed if of such capacity that it only necessitates periodic (but not frequent) clean-outs of deposited salt before it reaches constricting valves. As a matter of operating technique, the diaphragm-motor pressure is purposely momentarily fluctuated a number of times every day from fully open to fully closed position. This tests the response of the valve to repositioning.

Worry over the extreme length of the control valve air line from "B" to "E" proved to be groundless. The only changes necessary after the original installation were to cut the line in several places and insert water traps to be drained at intervals. Under different conditions of humidity in other climates it is conceivable that excessively long air lines would give some trouble.

We may sum up this problem as being one of the control and balancing of inter-related processes situated long distances apart and entailing the handling of saturated saline solutions. The type of instrumentation evolved to meet this problem is submitted with the conviction that its use will find more general application.

A System of Interlocking Air-operated Controllers Applied to Oil Cracking

By SELIG H. ISAACS

Instrument Engineer, Latonia Refining Corp., Latonia, Ky.

Awarded an Honorable Mention in the First Annual Instrumentation Contest

IN the operation of a certain type of oil cracking unit the problem arose of controlling the top temperature of a distillation tower and the liquid level and temperature of an accumulator automatically with a single stream of oil. This operation had previously been carried out manually, but the difficulties attendant upon such hand control are soon apparent from a study of the process. Serious upsets to the entire system can easily be brought about by the slightest negligence on the part of the operator or by his inability to instantly analyze the ultimate effects of a small change in conditions.

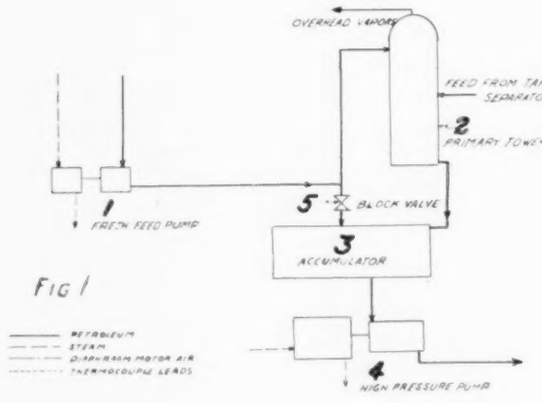


FIG 1

FIG 2

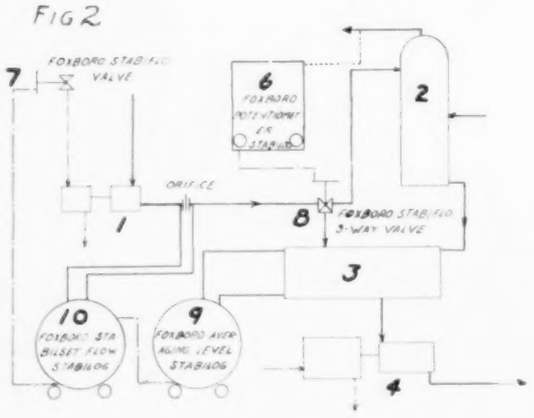


Fig. 1 is a flow sheet of that part of the process to which the control system had to be applied. From this figure it is obvious that sufficient liquid must be maintained in the accumulator (item 3) to give the high-pressure pump (item 4) full suction. Item 4 is a steam turbine driven centrifugal pump discharging at 1250 lbs./in.^{2} from 10,000 to 18,000 gallons per hour. This discharge flow is maintained constant at any point in the above range by a "Stabilog" flow controller. In order to satisfactorily control the temperature of the oil leaving the heater coil to which item 4 discharges, the temperature of the oil in item 3 must be reasonably constant. It is, furthermore, fundamental to the operation of the succeeding distillation process that the overhead vapors from the primary distillation tower (item 2) be of uniform and constant composition and temperature.

When on full manual control, it is necessary for the operator to adjust the speed of the pump (item 1) and the opening of the block valve (item 5) to the exact balancing point for correct top of tower temperature and correct accumulator level. A change in steam pressure on the steam end of item 1 immediately puts less material to both the tower top and the accumulator. This allows the temperature of the top of item 2 to rise, changing the composition of the vapors to the remainder of the distillation system and allowing less material to fall to the accumulator through the primary tower bottoms because of the increased vaporization. This adds to the loss sustained by the lowered flow through the block valve and the accumulator level begins to recede. Similar examples of other and more complicated upsets could be assembled to show the necessity of automatic control.

In Fig. 2 a complete automatic control system for this portion of the unit, including three controllers and two controlled valves, is shown. Note that, though the Foxboro Company's "Stabilog" equipment is herein specified and referred to, this has only been done to make clear the exact type of controller necessary. Equivalent equipment of any of a number of manufacturers would be equally applicable.

To follow through the operation of this control system let us assume that the Flow "Stabilog" with "Stabilset" mechanism (item 10) is set at some predetermined rate. This will deliver to the three-way "Stabiflo" Valve (item 8) a constant volume of fresh feed to be split to the tower and the accumulator. Item 6, a Potentiometer "Stabilog," has its thermocouple inserted in the overhead vapors line from the primary tower and its diaphragm-motor air line to the three-way valve. This permits the exact amount of

material required to hold a constant primary tower overhead temperature to pass through one discharge port of the three-way valve, and the remainder to be automatically dumped to the accumulator. Should the arbitrary rate of flow set on item 10 not be correct to maintain an average level in the accumulator, the averaging type liquid level "Stabilog" (item 9) will reset the control point of the flow controller through its "Stabilset" mechanism to give the correct flow. The differential type of liquid level measurement is felt desirable in this system for various mechanical reasons. Since the averaging type liquid level controller will make comparatively slow changes in the control point of item 10, and since the amount of material required by the top of item 2 will be fairly constant, or will in any case vary gradually, changes in the amount of cold material (i.e. fresh feed) to the accumulator will be gradual and will therefore make only slow changes in the accumulator temperature. These changes will be of such a nature as to have little upsetting effect on any Transfer Out Temperature Controller which may be used in connection with the high-pressure oil heater following item 4.

Thus the problem of controlling the top temperature of a tower and the liquid level and temperature of an accumulator with a single stream has been solved.

An Unusual Temperature-controller Job

By V. H. HIERMEIER

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Awarded an Honorable Mention in the First Annual Instrumentation Contest

IN that temperature is controlled by a temperature controller, the application described herein is ordinary. However, it is seen to be unusual when its important place in a complex array of inter-related processes is appreciated. The recording temperature controller, potentiometer type, in the upper right hand corner of the sketch, controls the temperature of the top of the main fractionating column. To show the unusual job this control has to do, we will trace what would happen without it.

First, we assure that the top temperature on the main fractionator has gone up several degrees. To overcome this we need more reflux. Thus the discharge pressure on pump "A" is dropped slightly, causing a surge in the main receiver, as the level is dropped due to the lower back pressure on the discharge of the level control valve. When this takes place inside the main receiver it momentarily drops the pressure in this vessel.

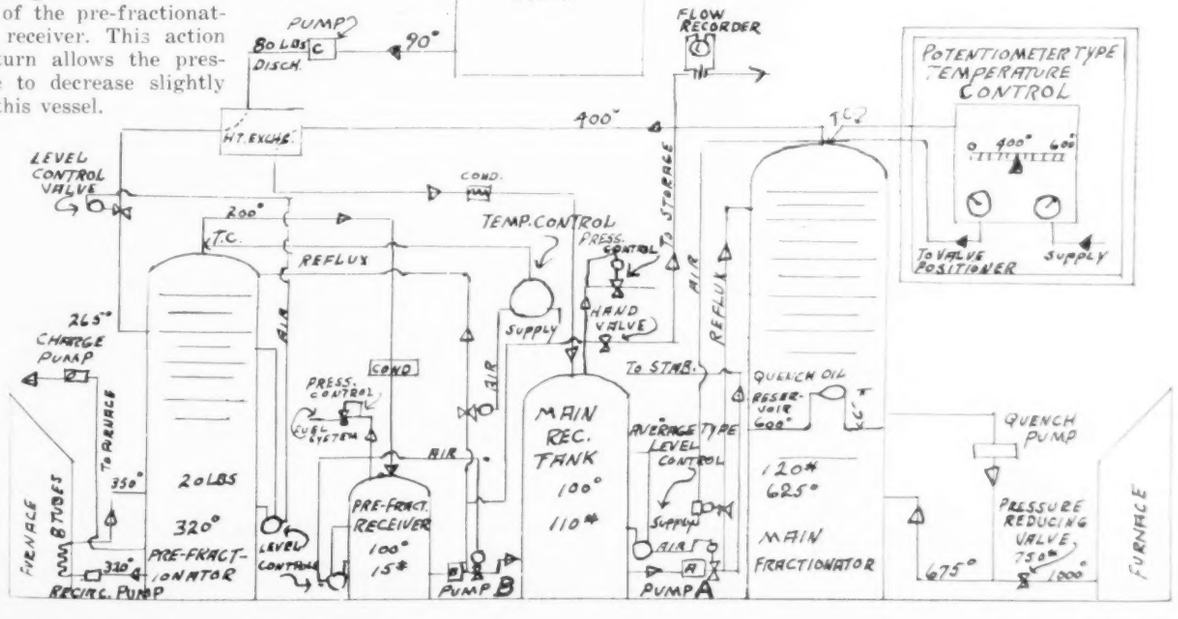
Since about 30% of the liquid in the main receiver comes from the pre-fractionating column receiver, through its level control, the discharge on that control valve will drop due to the lower pressure in the main receiver, or the point of about 30% discharge. Some of the remaining 70% is used as reflux to the pre-fractionating column.

As we also have a control valve on this line, its flow will be changed due to the lower pressure on the discharge of pump "B." This pressure drop will decrease the reflux to the pre-fractionating column, allowing its temperature to rise, thus decreasing the flow in the top of the pre-fractionating receiver. This action in turn allows the pressure to decrease slightly in this vessel.

As the rate of reflux decreases in the pre-fractionating column and the top temperature rises, the pressure will decrease momentarily in the column, which tends to set up a surge. Since we have a level control on this column with the control valve in the discharge of pump "C" from storage, we find, in cutting the reflux, and decreasing the pressure on the column, that we also lower the discharge on the level control valve allowing more liquid to enter the column. Thus another surge is started.

Since the charging pump "D" takes suction from the bottom of the pre-fractionating column, at the rate of approximately 250 gallons per minute controlled by a rate-of-flow control, actuating the speed of the pump, it is readily seen that the pressure, at the point of suction, should be practically constant. Assuming that the pressure in the pre-fractionating column is not constant, as has been previously pointed out, the rate-of-flow control governing the speed of the charging pump, will have to make adjustments for changes in the pre-fractionating column. This will vary the rate of flow through the furnace, thence to main fractionating column—the point at which the first upset took place—tending to continue the upset cycle.

It has been proven that, by holding the top temperature, on the main fractionating column, within ±1.5°F. of the control point, the rest of the controls will be able to properly take care of their respective jobs. But if the cycle is started as described, it is practically impossible to expect a uniform product.



Relative Volumetric Gas Analysis

by Cascaded Absorption and Oxidation and Pressure Recorder

By SHERMAN CHASE

Steam Engineer, Carnegie-Illinois Steel Corp., South Works, Chicago, Ill.

Awarded a Fifth Prize in the First Annual Instrumentation Contest

CORRELATION of gas analysis with operating data has usually been desirable in combustion work, and development of equipment for recording gas analysis has brought forth instruments of various designs for recording or indicating at least one and not more than two of the constituents of a mixed gas.

Certain gases resulting from the combustion of fuels contain the following gases:—carbon dioxide, carbon monoxide, hydrogen, and nitrogen, all in variable amounts. If an instrument indicates or records but one or two of these gases, only one's judgment or a complete gas analysis is available to determine in what proportions the others are present.

Multi-point temperature recorders have been available for some time which record the temperatures at various locations, or on several furnaces by means of printed numerals, colored inks, or other distinguishing marks, and an operator at any time may ascertain at a glance the temperature condition at many points. It may well be asked, can this not be done similarly in determining the constituents of mixed gases?

The method presented here for multiple recording of gas analysis consisted of a practical arrangement for indicating or recording the continuous analysis of gases containing carbon dioxide, carbon monoxide, hydrogen and nitrogen, utilizing a pressure recorder, range 0-0.2 inches of water. With variations, the method may be applied to other gases, including flue or stack gases.

The flow of gases through an orifice discharging to atmosphere is proportional to the square root of the pressure ahead of the orifice plate, and inversely proportional to the square root of the density of the gases. It may be expressed as follows:

$$Q = K\sqrt{(h/d)} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where Q = volume per unit of time; K = an orifice constant; h = pressure ahead of orifice; and d = density of gases or weight per unit of volume

Rearranging:

$$h = Q^2dK^2 \text{ or } h = QQdK^2$$

Now, if we substitute for Qd its equivalent weight W and assume K or K^2 equals unity, which may be done by choosing the proper time unit to correspond, the formula expressing the flow of gases through an orifice becomes simply:

$$h = QW \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where h = pressure ahead of the orifice; Q = volume of flow per unit of time; and W = weight of gases flowing per unit of time.

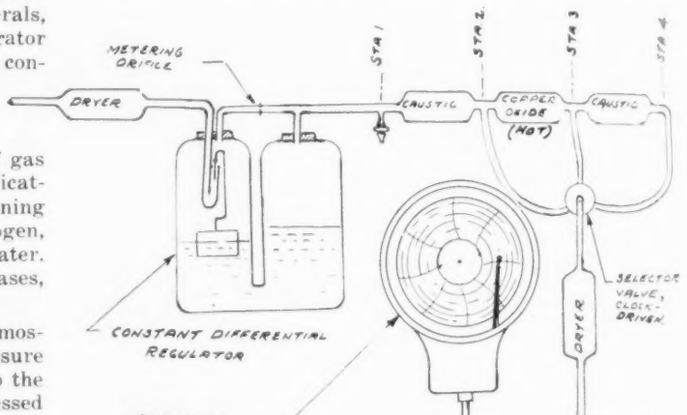
In order to further simplify calculations relative to flow of gases, and since only relative values are desired in a gas analysis, it was desirable to attach a broad meaning to the term W. This was accomplished by using a density factor, the determination of which becomes evident in examination of the following table.

TABLE I

Gas	Wt/cu. ft.—lbs.	Relative Density factor D
Nitrogen	0.07405	1.0
Carbon Monoxide	0.07403	1.0
Hydrogen	0.005323	0.072
Carbon Dioxide	0.11692	1.58

Assuming further, that the flow of gas through an orifice plate discharging to atmosphere is nitrogen in rate of flow equal to unity, discharge orifice pressure equal to unity, and with a relative density of unity, formula (2), $h = QW$, may be expressed as $h = Q \times Q \times D$ or $1 = 1 \times 1 \times 1$. Now, if in place of nitrogen flowing through the discharge orifice plate, a half-and-half dry mixture of nitrogen and carbon monoxide be passed through the same orifice plate, at unity orifice pressure, no external evidence of change could be noted. If, however, the same quantity of mixed gases were to be passed periodically over heated copper oxide, and the resultant carbon dioxide absorbed by caustic, it would be noticed that the pressure on the orifice plate would also change periodically from unity to 0.25 of unity, and it could be deduced that each of the gases were fifty percent of the total gases.

Since the sequence of oxidation and absorption may be cascaded in a gas analyzing apparatus and gases permitted



to flow periodically through a discharge orifice plate from any point of the sequence, it became evident that it was possible to analyze several gases volumetrically, by observing or recording the orifice pressure corresponding to a complete cycle of sequence of absorptions and oxidations.

The accompanying diagram shows equipment used to completely analyze the mixture of gases containing carbon dioxide, carbon monoxide, hydrogen and nitrogen. A constant-differential orifice flow regulator was provided to furnish a sample equivalent in QW value to nitrogen flow required to cause a pressure of unity at the discharge orifice (by-pass stations 2, 3, and 4). This did not necessarily mean that the quantity was actually unity based on the actual percentage of nitrogen present and was actually of no importance, since 0.98, 0.75 or any other value on the chart could be assumed to be unity flow.

The sequence of analysis was as follows:—A dried sample of the gases to be analyzed was allowed to flow through the constant-differential regulator, through a caustic, thence through heated copper oxide, again through caustic, through a selector valve, a drying chamber, and then a measuring orifice plate. The pressure on the orifice plate was continually recorded on a chart. With this sequence, it will be observed that all the gases in the sample were removed with the exception of nitrogen, the relative quantity of which in flow in terms of nitrogen was determined by simply extracting the square root of discharge orifice pressure.

The selector valve driven by clock mechanism, however, impresses periodically the resultant pressure on the orifice plate directly after the first caustic absorption and also after oxidation by copper oxide. Hence, the resultant QW

value (see formula 2) corresponding to each volume change in terms of unity total flow, in terms of nitrogen, was recorded.

In the following series of formulas, it will be noted that each formula has one more unknown value than that following. It is also evident that formulas containing but one unknown value may be solved.

Station No.

1 $Q_1 = (N_2 + CO + H_2) + CO_2$

2 $Q_2 = (N_2 + CO) + H_2$

3 $Q_3 = (N) + CO$ (CO as an equal volume of CO_2)

4 $Q_4 = N$

Then by formula (2) the orifice pressures which were obtained at stations 1, 2, 3, and 4 could be expressed as follows:

Station No.

*1 formula (3) $h_1 = [(N_2 + CO + 0.072\ H_2) + 1.58\ CO_2]\ [N_2 + CO + H_2 + CO_2]$

2 formula (4) $h_2 = [(N_2 + CO) + 0.072\ H_2]\ [N_2 + CO + H_2]$

3 formula (5) $h_3 = [(N_2 + 1.58\ CO)]\ [N_2 + CO]$

4 formula (6) $h_4 = (N_2)^2$.

*(At station No. 1, the flow was adjusted to $h = 1$ based on nitrogen)

Inspection will reveal that the above formulas are but a form of formula (2) $h = QW$ or $h = Q \times Q \times D$. Also, it is evident that, with the recording of h, the formulas may be evaluated in the following order:—6, 5, 4, and 3.

It may be noted, therefore, that with a few additions, such a simple instrument as a low-range pressure recorder may be converted into a mechanism capable of recording complex chemical analyses.

Unusual Application of a General Electric Torque Balance Watt Telemeter

By CHARLES WASSERMAN

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Awarded a Fifth Prize in the First Annual Instrumentation Contest

RECENT additional power requirements of a large consumer introduced a metering problem that was met in a unique manner. As shown in Fig. 1, this customer maintains a generating plant at "A" and was originally interconnected to the local utility through only one attended sub-station "B." The additional power requirements were supplied by the local utility through the customer's unattended stations "C" and "D." These various stations are widely separated.

The necessary metering called for a continuous record and hourly integration of the customer's total plant load. The existing torque balance watt-telemetering system connected to a recorder at station "A" to obtain the total plant load record, was extended to include stations "C" and "D." The problem of obtaining hourly readings of the billing watthour meters measuring the power interchange through these unattended stations was studied and two methods were considered.

Using watthour meter contact devices to operate distant dial equipment at station "A" would require the use of additional watthour meters to operate the contact devices, contact totalizing relays and additional communication channels between stations "C," "D" and "A." The purpose of installing additional watthour meters to operate the contact devices is to conform with the practice of keeping the billing watthour meters, measuring large blocks of energy, free of auxiliary devices. Furthermore the possible installation in the near future of other unattended supply points would further reduce the reliability of this method and our past experience of a similar installation justified the investigation of an alternate method that was available to obtain the desired results.

The possibility of integrating the telemeter output current of the unattended stations at station "A" provided another means of obtaining the hourly integration of the power interchange. The full load value of this output circuit current is 12 milliamperes direct current, equivalent to a primary load of 60,000 kw., and it is duo-directional. The use of d-c. watthour meters was considered unsatisfactory due to the difficulty of maintaining their accuracy within required limits below 10% load rating and the necessity of obtaining a definite constant d-c. voltage supply. Means of obtaining an a-c. wattage proportional to the output circuit current, so that a-c. watthour meters could be used, would have to be practically instantaneous due to the highly variable character of the load interchange. This was accomplished by making minor wiring changes to a standard General Electric torque balance watt-telemeter so that the function of the measuring elements could be reversed.

The standard watt-telemeter primarily consists of two measuring elements, a wattmeter operating element and a d'Arsonval restraining element, mechanically coupled and controlling the position of a light beam with respect to the two photoelectric cells by means of a mirror fastened to the coupling unit. These cells in turn control the plate current of the pliotron tubes, the difference of these currents normally are passed through the restraining element thereby producing a d-c.

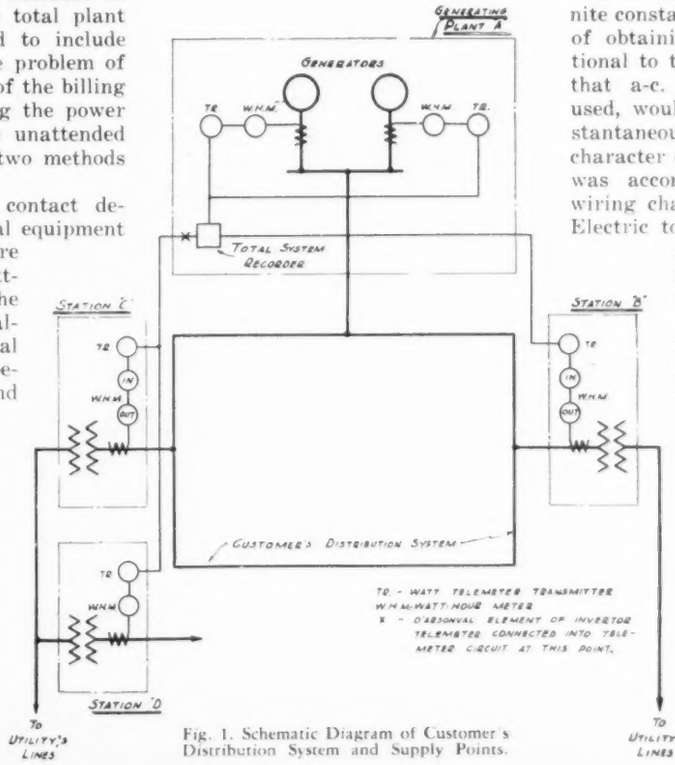


Fig. 1. Schematic Diagram of Customer's Distribution System and Supply Points.

current proportional to the watts measured.

As shown in Fig. 2 the d'Arsonval element was disconnected from the pliotron circuit, its leads brought to separate terminals and connected to the unattended stations' telemeter output circuit and now acts as the operating element. The plate circuits of the pliotron tubes were rearranged and resistors X1 and X2 were inserted in the plate windings of the telemeter control transformer as shown so that the magnitude and polarity of the voltage difference across these resistors will depend upon the relation of the plate currents of these tubes. This voltage is then applied to the input circuit of a simple amplifier which is energized from the same 120-volt 25-cycle unregulated source that supplies the wattmeter element voltage coil and the telemeter control circuit. The amplifier output, capable of delivering 7 amps 25-cycle into a 0.4-ohm impedance, is connected to the wattmeter element current coil, thereby providing the restraining torque.

The telemeter elements are calibrated so that 12 milliamps input will produce a phantom load of 400 watts applied to the wattmeter element to obtain torque balance between elements and the equipment automatically compensates the restraining torque for variation of the supply voltage. Two standard a-c. watthour meters, equipped with ratchet devices and having registers of proper ratio, are connected to integrate the wattmeter element phantom load circuit in terms of primary load interchange. External light-load and full-load adjustments are provided to correct for the zero errors of the unattended station telemeter transmitters and to compensate for differences in calibration between the billing watthour meters and the inverter watthour meter equipment.

This equipment has been in continuous service since Dec. 1, 1937. For five months a close watch was kept on its accuracy and reliability and in May, 1938, it became an integral part of the metering system. Up to the present time this equipment has not required servicing and the weekly comparison between the inverter meters and billing meters have been within ±1%. Basically this method is not as accurate as the contact device scheme when operating properly, but it obviates the need of additional metering equipment and communication channels at the present and future unattended stations and probably will require less maintenance.

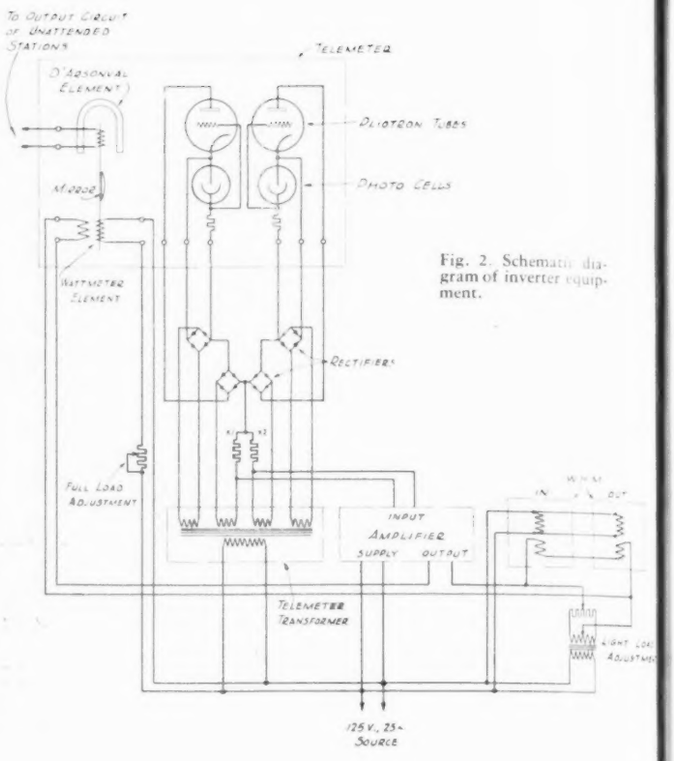


Fig. 2. Schematic diagram of inverter equipment.

Sugar Boiling by Instrument Control

By WALTER E. SMITH
Technologist, C. Brewer & Co., Ltd., Honolulu, T. H.

Awarded a Fourth Prize in the First Annual Instrumentation Contest

MENTION is made of the use of sugar and sugarcane in Chinese records antedating the birth of Christ. At that time sugar was a rare luxury. By the sixth century it appeared as an article of commerce. Before the end of the sixteenth century more than a hundred sugar mills were in operation in Brazil, producing fifteen thousand tons annually for export. Hence, we may well say that the problems of sugar manufacture parallel the development of industrial technology.

The fundamental chemical operation of recovering solids from solution by concentration to the density at which crystallization occurs was well known to the Egyptians. When Amru conquered Egypt in 640-646 A.D. he introduced the culture of sugarcane, and the Egyptians soon developed a process for the production of crystallized sugar.

Early practice consisted of boiling the purified juices in open kettles to a suitable concentration, so that on cooling a small yield of sugar crystals was obtained. In terms of modern procedure these earlier methods were obviously crude and inefficient, and no means of control were available until 1790 when it was discovered that the boiling temperature of a concentrated sugar solution was an index of the amount of sugar in solution and Dutrone published the first formal table showing this relationship. Dutrone advocated the use of a thermometer to determine the most suitable concentration to give the required size and yield of crystallized sugar.

In the original open-kettle process the concentration of sugar juices was performed at atmospheric pressure, resulting in high temperatures which caramelized the syrups and gave the resulting products a dark brown color and a somewhat unpleasant taste. The development of the vacuum pan in 1850 permitted boiling at much lower temperatures. Since then, commercial operations were concerned with the problem of "sugar boiling" on a more efficient basis.

Operating the vacuum pan to secure maximum yield of sugar and to produce crystals of the proper size now assumed importance, and gave high value to the skill of the workmen who controlled the performance of the vacuum pans. The success of these operations depended entirely on the skill of the operators, who relied on a great variety of indications, interpreted always on the basis of their personal judgment and experience. This gave rise to the expression: "the art of sugar boiling." Sugar boilers jealously guarded their secrets and would only instruct an apprentice on payment of a heavy tuition fee. Soon this group assumed an important position in the industry.

Even at that early date the need for more scientific control was appreciated, and various investigators attempted to extend the early work of Dutrone to the new conditions. Control of the early open-kettle boiling required only a simple temperature measurement, since the operation was always at atmospheric pressure, and the boiling point elevation was simply determined by subtracting 212° from the indicated temperature. But when boiling was performed under vacuum the actual temperature of the boiling mass no longer gave a direct indication of the boiling point eleva

tion for the variations in vacuum obviously affected the boiling temperature to an even greater extent than did the variations in concentration. About 1880 Seyferth developed the "Hypsometer" to meet this problem. This instrument was a combination of a thermometer and a barometer, so calibrated that the boiling point elevation could be determined by measuring the difference between the mercury columns of the two instruments.

Other workers modified the form of the instrument for greater convenience, but this basis did not permit anything other than manual control.

In 1930 the writer initiated a study of sugar boiling, in an effort to reduce the operation to a basis which would permit a truly automatic control, and to remove it from the field of purely empirical personal judgment. What follows is a résumé of the principles on which this control is based, and a description of the results attained.

In reviewing the literature of sugar boiling control the writer found the method of Langen, proposed shortly after 1900, which seemed to hold the essentials of a workable system. This method provided a receiver, connected to the vacuum space of the pan, in which a supply of water was held at the boiling point; thus, as the vacuum varied, the boiling temperature of the water varied to correspond to the changes in absolute pressure of the system. Langen inserted one end of a thermocouple into this water, and the other junction into the boiling sugar massecuite; then, since a thermocouple measures the difference in temperature between the junctions, the indication thus obtained was a direct measure of the difference between the boiling temperature of water and the sugar massecuite. This gives "boiling point elevation." While fundamentally sound, the method of Langen had attained no commercial success, and had found no application in industry.

Studies made by the writer showed that in order to be a practical basis of control the measurement of boiling point elevation must be most accurate, since an error of more than a fraction of a degree would produce improper results. Within the working range of about thirty degrees temperature difference, a thermocouple could not give an accuracy of better than one or two degrees, and since this was obviously too insensitive for the requirements of the control it explains the failure of the Langen method.

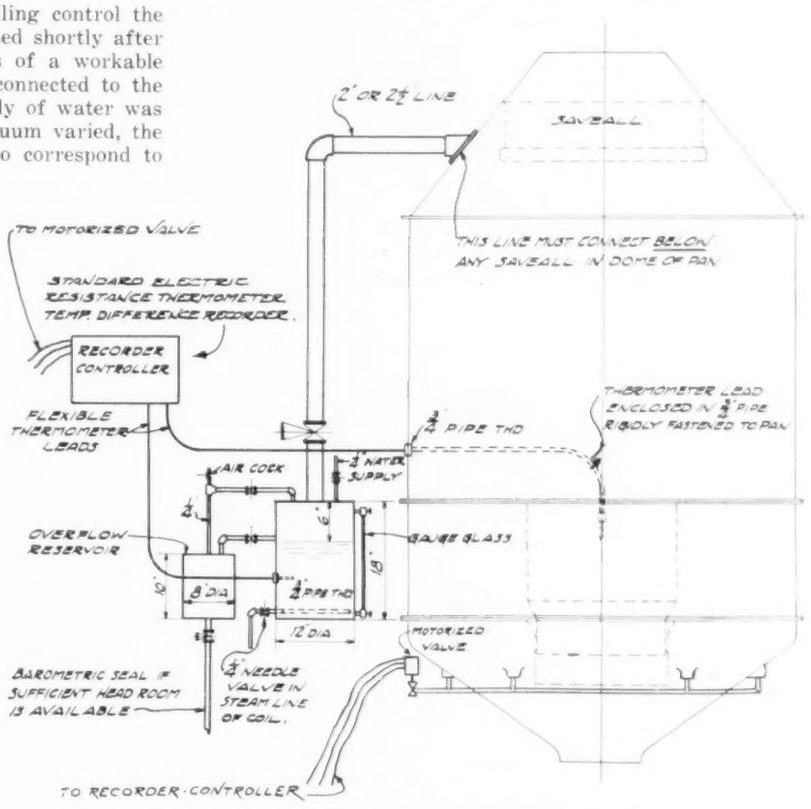
Modern electric resistance thermometers, capable of measuring temperature with great accuracy, were therefore substituted for Langen's thermocouples. One thermometer was inserted in the water, the other in the massecuite, and both thermometers were then connected into the arms of a Wheatstone bridge, thus measuring directly the "temperature difference" which constitutes boiling point elevation.

The first step was to purchase a standard temperature difference recorder, using electric resistance thermometers, and fitted with contacts to actuate the necessary control valves, and this instrument was applied to a vacuum pan at the factory of the Hilo Sugar Company, at Hilo, Hawaii. The arrangement is shown in the accompanying drawing.

The instrument was first allowed to operate as a simple recorder, with the operator controlling the boiling in the conventional manner. The record so produced showed that even under the best control based on judgment, the conditions varied considerably from what was later found to be the optimum control point. But examination of the record made it possible to determine the trend of the control sought by the operator, and permitted us to plot a typical ideal record. This done, the operator was instructed to manipulate the vacuum pan so as to reproduce the prepared curve. This established the fact that the operation thus secured was better than the best results based on personal judgment.

The next step was to actually *control* the admission of feed liquor to the vacuum pan by means of motorized valves commanded by the controller. This proved completely satisfactory, and the vacuum pan on which the first experiments were made is still controlled by the instrument. Proper values have been established for the various products boiled in the vacuum pans, and all the operator needs do is to set the control point at the selected value, the instrument then maintaining the proper concentration automatically. The results obtained are entirely consistent, and at this factory the chief point of concern is that the operators are losing their old skill. This would become bothersome in the event of accident to the control equipment, though this has proved most dependable.

This method of control is now used extensively throughout the sugar industry, and installations have been made in most of the sugar producing countries; and in Hawaii, noted for its scientific control, this method has found great favor. Instrumentation is still resisted, however, by a few of the old school who still choose to believe that human judgment cannot be replaced by man's mechanical ingenuity.


2" OR 2½ LINE
SAVEALL
TO MOTORIZED VALVE
THIS LINE MUST CONNECT BELOW ANY SAVEALL IN DOME OF PAN
STANDARD ELECTRIC RESISTANCE THERMOMETER TEMP. DIFFERENCE RECORDER.
RECORDER CONTROLLER
FLEXIBLE THERMOMETER LEADS
THERMOMETER LEAD ENCLOSED IN ¾" PIPE RIGIDLY FASTENED TO PAN
¾ PIPE THD
¾" WATER SUPPLY
AIR COCK
GAUGE GLASS
OVERFLOW RESERVOIR
8" DIA
½" PIPE THD
12" DIA
MOTORIZED VALVE
BAROMETRIC SEAL IF SUFFICIENT HEAD ROOM IS AVAILABLE
¾" NEEDLE VALVE IN STEAM LINE OF COIL.
TO RECORDER-CONTROLLER

An interesting sidelight on this development is seen in its effect on the design and operation of vacuum pans for sugar boiling. The application of this method of control to vacuum pans of old design quickly demonstrated the imperfect performance of the equipment. This gave new incentive to reconsideration of designs which had previously been thought entirely satisfactory, and has led to improvement in design to overcome these shortcomings. As a result modern equipment now used for sugar boiling is infinitely superior to that available ten years ago, and has resulted in material reductions in cost of operation. This effect alone has paid a hundred times over for the cost of the original investigation, and the end of improved developments is not in sight.

Training of sugar boilers becomes a job of weeks instead of years. Errors in manipulation are no longer possible, and this has resulted in an improvement in the product as well as in costs of production by avoiding expensive mistakes.

A patent has been granted on this method of vacuum pan control, even though the equipment used is standard with instrument manufacturers. The equipment used for this method of control is manufactured by Leeds & Northrup.

Magnetic Methods of Testing Hardness

By S. R. WILLIAMS
Professor of Physics, Amherst College

HARDNESS TESTING OF "ALL-OVER MACHINED" PRODUCTS BY MAGNETIC METHODS

If magnetic methods can be used for measuring hardness it is evident that their most practical applications would be to materials and particularly finished products where the use of the indentation, scratch or rebound method would be disastrous to further use of the specimen. On a high-grade steel ball, for example, an indentation method leaves the imprint of the diamond indenter which is a point of weakness for wear and breakage if that particular ball is used.

The making of steel balls calls for a high degree of precision in their size and also in their heat treatment. Such products, therefore, furnish good samples for applying magnetic methods to the testing of relative hardnesses, or for suitability of purpose.

The magnetic method finally employed in testing steel balls with different drawing temperatures was based on the principles that a steel ball when brought into a magnetic field will distort that field, and that the distortion will be greater the softer the ball, if size and uniformity of structure remain the same for all the balls tested.

The magnetic field to be distorted was provided by the combined fields of two horseshoe magnets arranged so that their fields opposed each other. Fig. 273 shows the magnetic hardometer as finally employed and Fig. 274 shows the combined fields. The point *A*, Fig. 274, is a neutral point in the combined fields when a steel ball is placed between the poles of one magnet as in Fig. 275. The neutral point is displaced to *B* when the ball is removed. When the magnetometer, Fig. 273, is placed at *B*, Fig. 274, the introduction of a steel ball between the poles of Magnet 2 distorts the field, shifting the neutral point from *B* to *A* and thereby deflecting the magnetometer needle by an amount which is some function of the hardness of the steel ball.

The distance between the pole ends of the two magnets is about 20 cm. (7.8″) which brings the neutral points

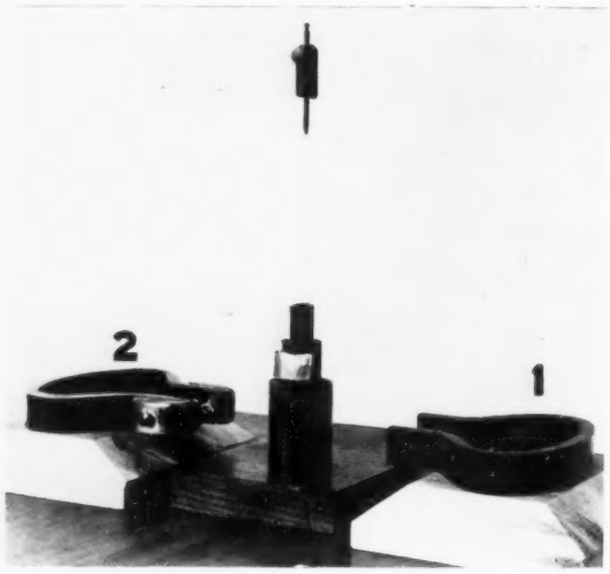


Fig. 273. The parts of the Magnetic Hardometer. A Magnetometer is set midway between the two horseshoe magnets, 1 and 2.

Fig. 275. This shows in greater detail how the ball is held in position between the poles of magnet 2 in Fig. 273.

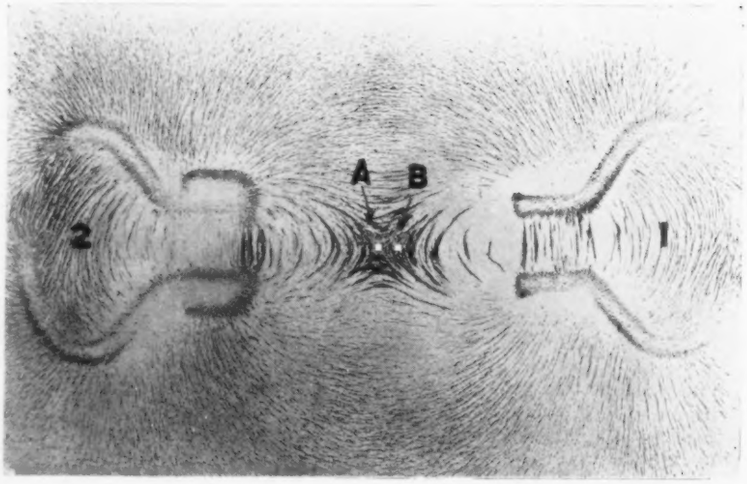


Fig. 274. Two permanent magnets were set up with their fields opposing each other. The distortion of these combined fields by the introduction of a steel ball between the poles of magnet 2 produced a deflection of the magnetometer needle.

about 10 cm. (3.9″) from each magnet. Fig. 274 shows how sharply the neutral point is defined. If a short magnetic needle is used the displacement of the neutral point by the steel ball would cause a deflection of the magnetometer needle through an angle of 180°. A long needle, like the one used in a surveyor's transit, would indicate little change in the field. The magnetometer needle used in this work was bell-shaped as shown in Fig. 276 which shows several sizes and combinations for making an astatic magnetic needle. The new magnetic alloys, such as the General Electric Co.'s Alnico, should make excellent bell-shaped magnets.

The bell-shaped magnet was attached to a stiff brass shank as shown in Fig. 276, to which a mirror was also

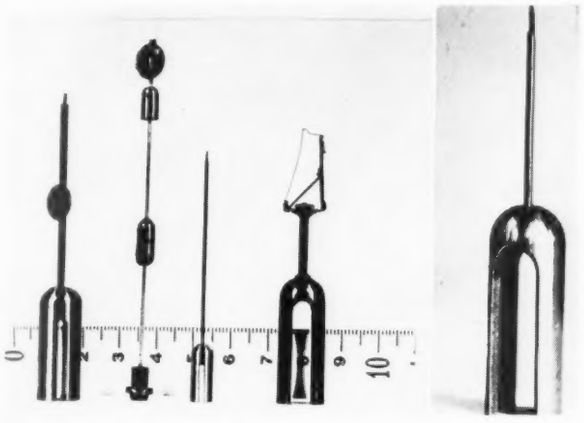


Fig. 276. Various sizes and combinations of bell-shaped magnets to be used in magnetometers.

fastened and the whole system suspended by a fine phosphor-bronze fiber *P*, as shown in Fig. 277. By use of a telescope and scale the deflections of the needle could be observed in the mirror. In order to dampen the oscillations of the needle, the latter swung in a heavy brass cup *A*, filled with a light transformer oil. See Fig. 277. Inasmuch as the scale readings became an arbitrary set of numbers for hardness, the scale was reversed so that deflections giving small numbers corresponded to soft balls and large numbers to hard balls. Because the length of the magnetometer needle has a great deal to do with the sensitivity of the outfit, the position of the magnetometer between the two horse-shoe magnets seems to be a matter of cut-and-try. Once a good location has been found, the whole outfit may be picked up, transported and turned in any direction desired. Standardization of any magnetic hardometer must be in terms of a standard steel ball.

It seemed desirable that when a steel ball of a given size was placed between the poles of magnet No. 2 (Fig. 273) it should come as near filling the gap as possible, so extra pole-pieces were attached to the permanent magnets, as shown in Fig. 275. This cut shows the ball in position, being held there by the magnetic attraction of the pole. In the faces of the pole-pieces small conical depressions are made which insured the steel balls being seated each time in exactly the same position. Fig. 273 shows only one of the magnets with the extra pole-pieces. In practice both magnets carried the extensions of poles so that with the two different-size gaps between the poles several sizes of steel balls could be tested without changing the extra pole-pieces.

The horse-shoe magnets were obtained from the Rawson Electrical Instrument Co. of Cambridge, Mass. The total flux of these magnets was 17500 maxwells for magnet No. 1 and 17890 maxwells for magnet No. 2.

The criticism has been made that if the steel ball is rotated, after being placed between the poles of the magnet, an entirely different reading will be obtained because of the retentivity of the steel along the direction first magnetized. This is a just criticism. To obviate this difficulty the balls were placed directly between the poles

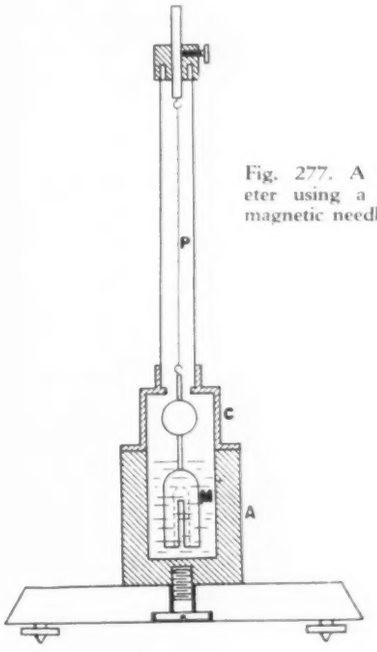


Fig. 277. A magnetometer using a bell-shaped magnetic needle.

without rotation. If a second reading was desired the ball was removed and allowed to roll through a solenoid through which an alternating current was flowing. This coil was 32.9 cm. long and 3.5 cm. in free diameter with a constant of 44.8 gauss per ampere. When it was connected to a 110-volt alternating-current supply, a current of about 7.5 amperes flowed in the coil. The rolling ball passing through the strong alternating field at the center of the solenoid, and then on through and out some distance from it, was found to be thoroughly demagnetized; it could again be placed in the magnetic hardometer and tested as before. Balls classified for different degrees of hardness showed a similar classification after having been demagnetized in the manner described. There was some indication that a few showed a small decrease in hardness. It has been noticed elsewhere that the process of magnetization changes slightly the hardness of some steels.[1]

It must be remembered that the magnetic test includes the interior condition of the ball, while the Rockwell test is one of the surface layers only. If the steel balls were not homogeneous it probably would not be possible to work out a satisfactory set of conversion factors between Rockwell and magnetic numbers.

One of the first tests carried out was a series of readings on a set of steel balls, $\frac{3}{4}$″ in diameter, which had different drawing temperatures: these readings were then compared with the rebound tests and the Rockwell numbers. The balls with different drawing temperatures were demagnetized in the fashion just described before the following readings were taken. There were three balls

[1] S. R. Williams, A Correlation Between the Mechanical Hardness and the Magnetostrictive Effects of Ferromagnetic Substances. *Transactions Amer. Soc. Steel Treating*, Vol. 5, 1924, pages 362-368.

to each temperature, and four different temperatures: 480, 660, 840 and 1020° F. The readings on the three different balls for each temperature were averaged together for the values given in Fig. 278; but in Table I the individual readings for the different balls are indicated and will give some idea of the way in which the magnetic numbers run on the magnetic hardometer.

TABLE I—MAGNETIC NUMBERS

	Drawing Temperature, 480° F.				
Ball No. 1	65.0	65.6	65.5	65.4	Average value 65.0
Ball No. 2	65.5	65.7	65.0	65.4	
Ball No. 3	64.3	64.3	63.9	64.2	
	Drawing Temperature, 660° F.				
Ball No. 1	61.5	61.0	61.0	61.2	Average value 61.1
Ball No. 2	60.0	61.5	61.0	60.8	
Ball No. 3	61.9	61.3	61.1	61.4	
	Drawing Temperature, 840° F.				
Ball No. 1	53.7	52.3	52.5	.....	Average value 53.2
Ball No. 2	54.0	53.3	53.2	.....	
Ball No. 3	53.3	53.2	52.9	.....	
	Drawing Temperature, 1020° F.				
Ball No. 1	53.5	53.3	52.3	.....	Average value 52.9
Ball No. 2	53.3	53.0	52.8	.....	
Ball No. 3	53.2	52.5	52.3	.....	

A series of readings was then taken on these same balls by the rebound method. The striking surface for the balls was the polished surface of a hard anvil. On the various surfaces thus tried out the old anvil with its surface smoothed off gave the best results. The rebound numbers are tabulated in Table II.

TABLE II—REBOUND METHOD

Rebound numbers = Height of rebound in centimeters
Dropping height = 70cm.

	Drawing Temperature, 480° F.			
Ball No. 1	66.2	66.3	66.2	Average number 66.3
Ball No. 2	66.0	66.5	66.5	
Ball No. 3	66.2	66.5	66.3	
	Drawing Temperature, 660° F.			
Ball No. 1	65.8	65.6	66.0	Average number 65.8
Ball No. 2	65.9	65.7	66.0	
Ball No. 3	65.5	65.8	66.1	
	Drawing Temperature, 840° F.			
Ball No. 1	64.6	64.8	64.8	Average number 64.6
Ball No. 2	64.5	64.2	64.2	
Ball No. 3	64.6	64.8	64.9	
	Drawing Temperature 1020° F.			
Ball No. 1	62.0	62.5	62.6	Average number 62.4
Ball No. 2	61.9	62.2	62.1	
Ball No. 3	62.5	62.6	62.6	

The same series of balls was next tested by the Rockwell hardness tester. Inasmuch as this instrument left indentations in the balls which would influence magnetic tests, only one ball was taken from each drawing temperature. The readings for the different Rockwell numbers were taken at random around the ball and are given in Table III. (The balls selected were those showing the largest magnetic numbers recorded in Table I.)

TABLE III—ROCKWELL NUMBERS

Tempering Temperature 480° F. Ball No. 1	Tempering Temperature 660° F. Ball No. 2	Tempering Temperature 840° F. Ball No. 2	Tempering Temperature 1020° F. Ball No. 3
67.3	64.2	59.6	57.7
66.6	64.2	59.6	57.9
67.0	64.2	59.8	58.0
67.0	64.2	60.1	58.0
66.8	64.0	59.7	57.7
67.1	64.0	60.0	57.6
66.9	64.5	59.4	57.9
66.8	63.6	59.3	57.8
67.1	64.4	59.6	57.9
66.9	64.5	59.3	57.5
67.0	63.9	59.5	57.9
67.7	64.3	59.5	58.1
67.0 Av.	64.1 Av.	59.5 Av.	57.8 Av.

A comparison of the three sets of readings is shown in Fig. 278. All of the readings are compared with the tempering temperatures. The Rockwell numbers are a measure of indentation hardness and express this property in terms of plasticity while the rebound numbers measure the elastic properties of the metal.

The question may properly be raised, what do the magnetic numbers measure?

Steel balls are put on the market with a fairly definite heat treatment and for any particular brand should be quite uniform. It was of interest, therefore, to take a hundred steels balls, supposedly of the same origin and treatment, and see if the magnetic hardometer would differentiate them with respect to hardness. On a scale which could be moved into any position desired it was arranged that those balls which gave a reading between 73 and 69 would be classed as "very hard," between 69

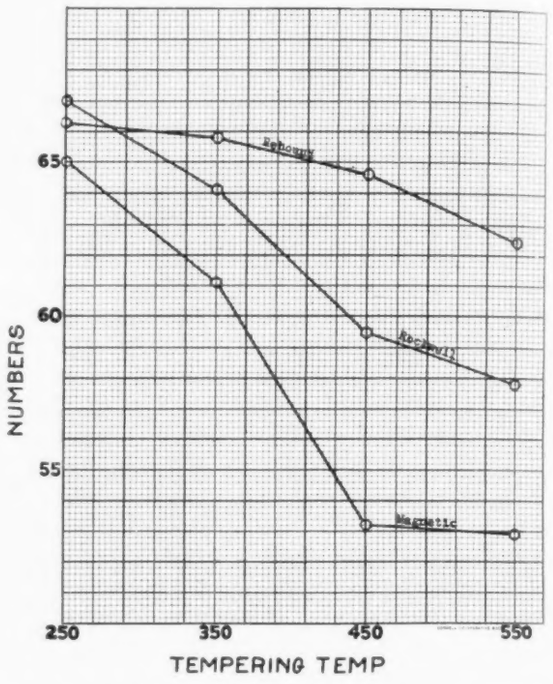


Fig. 278. Rockwell and rebound numbers compared with magnetic hardness numbers on a group of steel balls.

and 65 as "hard" 65 to 61 as "medium," 61 to 57 as "soft" and below 57 as "very soft." The distribution of these balls according to hardness follows roughly a general distribution law. The values for the rebound numbers are also given.

TABLE IV.

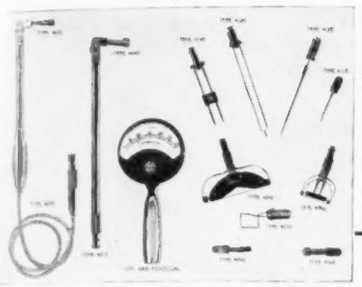
	"Very hard"	"Hard"	"Medium"	"Soft"	"Very soft"
No. of Balls	3	17	24	50	6
Magnetic Numbers	73-69	69-65	65-61	61-57	57-
Rebound Numbers	66.0-63.5	63.5-60.9	60.9-58.4	58.4-55.9	55.9-54.0

This set of balls was needed for further work and so the Rockwell hardness tester could not be applied to all of them. Two were selected, according to the magnetic numbers, one from the "very hard" and one from the "very soft." The records for these two are given in Table V. Values were taken 20 degrees apart in a circle around the balls.

TABLE V.

Very Hard Ball		Very Soft Ball	
Angles	Rockwell Numbers	Angles	Rockwell Numbers
0	65.8	0	63.4
20	66.3	20	65.2
40	66.5	40	65.1
60	66.4	60	65.2
80	65.8	80	65.3
100	65.7	100	65.3
120	66.2	120	65.2
160	66.1	160	65.3
140	66.0	140	65.3
180	66.3	180	64.9
200	66.0	200	65.3
220	66.2	220	65.2
240	66.1	240	65.3
260	66.3	260	65.2
280	66.3	280	65.0
300	66.5	300	65.0
320	66.0	320	65.2
340	66.1	340	65.2
	Av. 66.2		Av. 65.2

Continued on page 226



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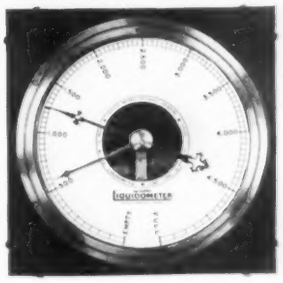

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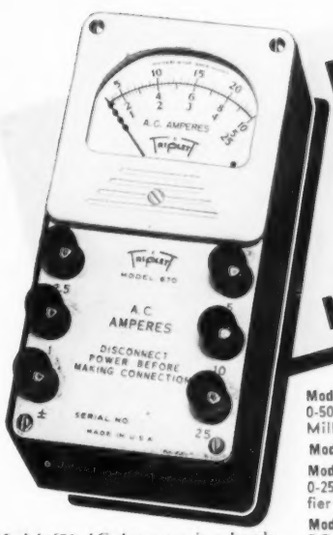

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Both Tables IV and V indicate that whatever property the magnetic numbers measure they are making that distinction very clear. In a previous paper[2] it was shown that those steel balls which were classified as uniform and hard by the magnetic tester gave the best record for crushing strength. In all cases the magnetic numbers seems to go progressively with those numbers which in other methods we call the hardness numbers of the material tested. Not only do they follow some law of comparison but the different degrees of hardness are indicated by larger steps in the magnetic numbers than by other methods, which makes the magnetic method an easy one to use. It is not clear just what the kind of hardness is which the magnetic hardometer measures, but Fig. 278 would indicate that it comes nearer to the Rockwell hardness numbers than to the others. Can we say that the magnetic numbers measure the resistance to penetration? Much more work must be done on the relation between magnetism and hardness before we can answer some of these questions. One cannot speak of the numbers which are obtained by the magnetic method as the magnetic hardness of the material for, as already pointed out, the term "magnetic hardness" has been frequently used to indicate the coercive force for saturation.[3] The use of such a term in our present problem would lead to misunderstandings, although it would more suitably be used in that connection than with coercive force. It may develop that coercive force and hardness as measured by the Rockwell tester do have a definite relation. Work by Nusbaum[4] indicates this possibility. Reference to this point has already been made and will be considered again in a subsequent section.

This magnetic method, as pointed out before, demands uniformity of structure throughout the ball. Otherwise one couldn't compare the results obtained magnetically with those taken with a Rockwell tester. The latter measures only surface conditions. In order to get more information on this point, a steel ball was cracked into two hemispheres and Rockwell hardness numbers taken along a diameter of one of the flat surfaces. These readings are shown in Table VI.

TABLE VI—ROCKWELL NUMBERS ALONG DIAMETER OF 7/16-INCH STEEL BALLS

Reading No.	1	2	3	4	5	6	7
Rockwell Numbers	66.0	66.5	66.8	66.4	66.2	66.6	66.3

This set of readings does not reveal any striking differences between the Rockwell numbers for the outer layers and the center.

Parts machined to definite and uniform size lend themselves to measurements by the magnetic method just described. In the days when the valve stems in automobile engines were made of ferromagnetic material it was possible to compare their hardnesses by this method. The magnets in Fig. 273 would simply have to have their special pole-pieces changed in form and different distances placed between the magnets.

The method as thus presented for picking out high-grade steel balls or other parts possessing uniformity without injuring them seems to present some possibilities. The magnetic method at the present time appears to have its chief value in the fact that it presents another angle from which to view the property called hardness as measured by other well-known methods.

MEASURING MECHANICAL HARDNESS BY MAGNETIC INSTRUMENTS

In this laboratory Smith,[5] using a Fahy's permeameter and its accessories as shown in Fig. 279, measured the hysteresis loss in a series of six steel rods whose heat treatment had been uniform for all the rods. These same rods will appear again in later discussions as quite a bit of work has been done on them. Their chemical constitution and physical make-up are given in Table VII.

TABLE VII

Rod	Cross-sect. area, cm.^{2}	Carbon %	Manganese %	Phosphorus %	Sulphur %	Hardness Number
A_6	0.326	0.11	0.49	0.010	0.039	B-64.2
B_6	0.325	0.31	0.53	0.012	0.039	B-77.1
C_6	0.320	0.49	0.41	0.012	0.033	B-83.5
D_6	0.318	0.69	0.48	0.019	0.033	B-94.5
E_6	0.322	0.91	0.44	0.023	0.027	B-97.3
F_6	0.320	1.11	0.42	0.019	0.036	B-99.9

In Fig. 280 are shown the hysteresis curves drawn for the six rods. Once these have been obtained it becomes

[2] S. R. Williams. Hardness of Steel Balls by magnetic tests. *Transactions Amer. Soc. Steel Treating*, Vol. 5, 1924, pages 479-484. Hardness Testing of Steel Balls by Magnetic Methods. *Transactions Amer. Soc. Steel Treating*, Vol. 8, 1927, pages 677-823.

[3] L. W. Wild. A Method of Measuring the Magnetic Hardness of Ferrous Metals and its Utility for Carrying Out Research Work on Thermal Treatment. *Transactions Faraday Society*, Vol. 15, 1920, pages 1-15.

[4] C. Nusbaum. Certain Aspects of Magnetic Analysis. *Proceedings Amer. Soc. Testing Materials*, Vol. 19, 1919, pages 91-112.

[5] H. H. Smith. Measuring Mechanical Hardness by Magnetic Instruments. *Instruments*, Vol. 7, 1934, pages 23-24.

Fig. 279. Fahy's Permeameter with some of its accessories.

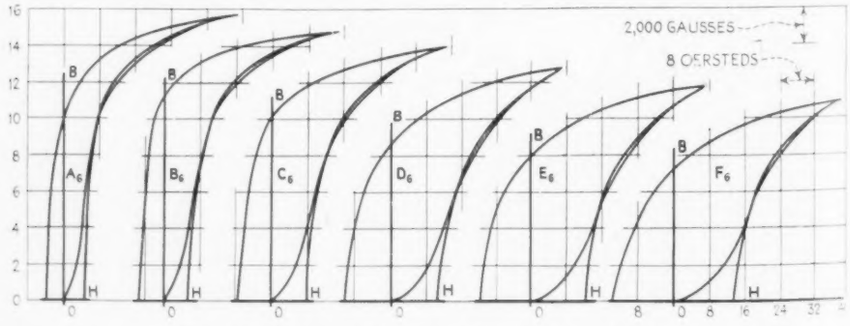

Fig. 280. Hysteresis loss curves for the six steel rods.

Only half of each loop is shown.
Curves for the six specimens are all drawn to the same scale.
Abscissas represent magnetizing forces.
Ordinates represent induction.
$H_{max} = 39.2$ gilberts/cm.

The hysteresis loss in ergs cm^3/cycle for each rod is as follows:
$A_6 = 19600$ $D_6 = 37760$
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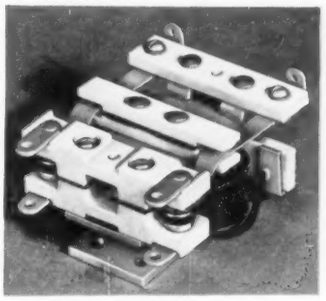

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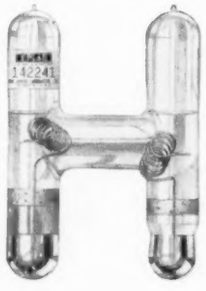

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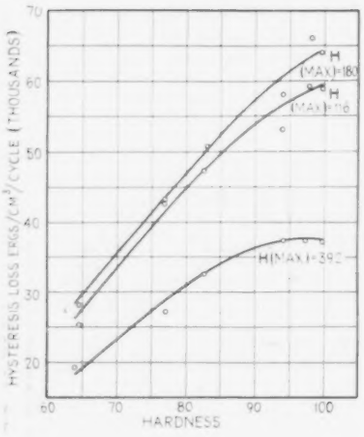

Fig. 281. Relation between Hardness and Hysteresis Loss.

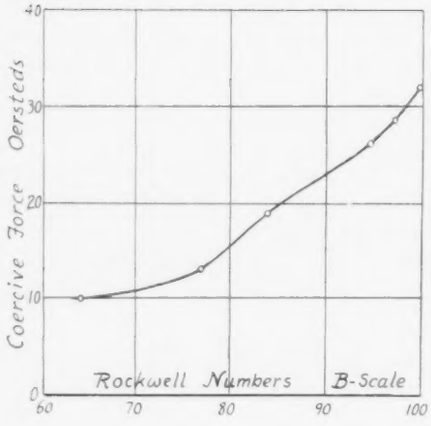

Fig. 282. Relation between Hardness and Coercive Force.

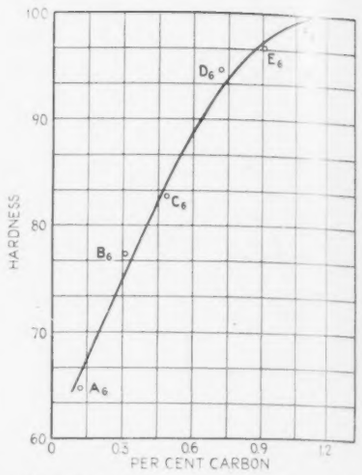

Fig. 283. Relation between Hardness and Carbon Content.

an easy matter to obtain numerical values for coercive forces, retentivities, hysteresis losses and permeabilities. Fig. 281 shows the relations between the Rockwell numbers and the hysteresis losses at various values of H_{max}. If the process of magnetization consists in flopping the axes of spin of the free negatrons around into a direction parallel to that of the direction of the magnetizing force, then it would appear why the hysteresis loss increases with increasing hardness. The very forces which bind the atoms together to increase the resistance to penetration of the hardness tester also augment the forces which restrain the spinning negatrons from being turned so that they are all more or less in a common

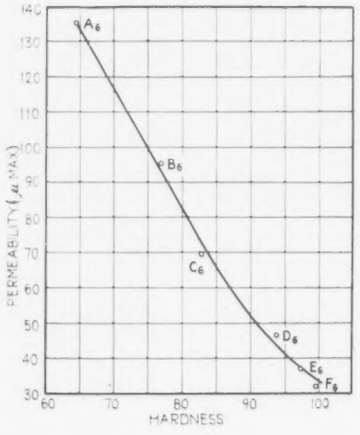

Fig. 284. Relation between Hardness and Permeability.

direction. As pointed out in an earlier chapter, we get down to fundamental facts concerning interatomic, intermolecular forces in dealing with hardness and with magnetic phenomena. On such an argument it would follow that in general the coercive forces should follow the hardness numbers.

In Fig. 282 the values of the coercive forces for the same six rods are plotted against their Rockwell numbers. This curve bears out the above statement that as the hardness increases so does the coercive force.

From Table VII the values of the carbon content for the six rods were taken and plotted against hardness. See Fig. 283. The hardness goes up with the carbon content. As more and more of those bonds (which hold carbon atoms together so solidly in the diamond, hardest of all solids) become effective, the harder becomes the steel under the same kind of heat treatment.

It naturally follows, as shown in Fig. 284, that the permeabilities of the rod would increase with increasing softness. The magnetic lines of force permeate the iron rods easier the less difficult it becomes for the gyroscopic negatrons to turn with their axes parallel to the magnetic field. This point seems to be substantiated in Fig. 284.

CORRECTION

In last month's instalment of this serial by Professor Williams, the letter R in the last formula at the bottom of page 190 (and in the caption of Fig. 266) should be omitted. Strike out also the words "and R the average radius of the turns" under the formula. Two lines above the formula, substitute "helix" for "spiral."

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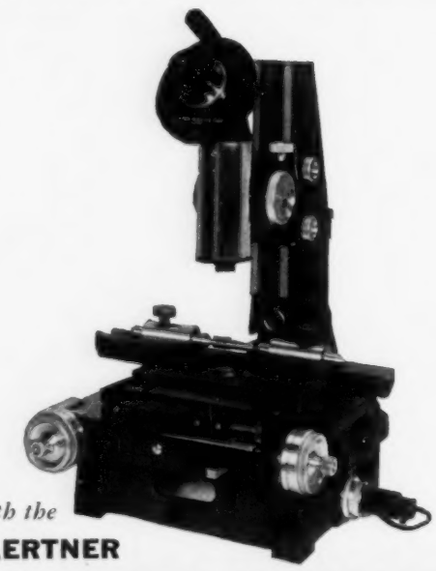

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